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Takenaga et al.

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(45) **Date of Patent: Jan. 24, 2017**

(54) **SHEET DISCRIMINATOR AND IMAGE FORMING APPARATUS INCORPORATING THE SHEET DISCRIMINATOR**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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Jul. 2, 2014 (JP) 2014-136498

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G01N 21/55 (2014.01)
G03G 15/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G03G 15/5029*** (2013.01); ***G01B 5/0023*** (2013.01); ***G01B 5/24*** (2013.01);
(Continued)

(58) **Field of Classification Search**
USPC 356/445–448, 429–430, 625–640
See application file for complete search history.

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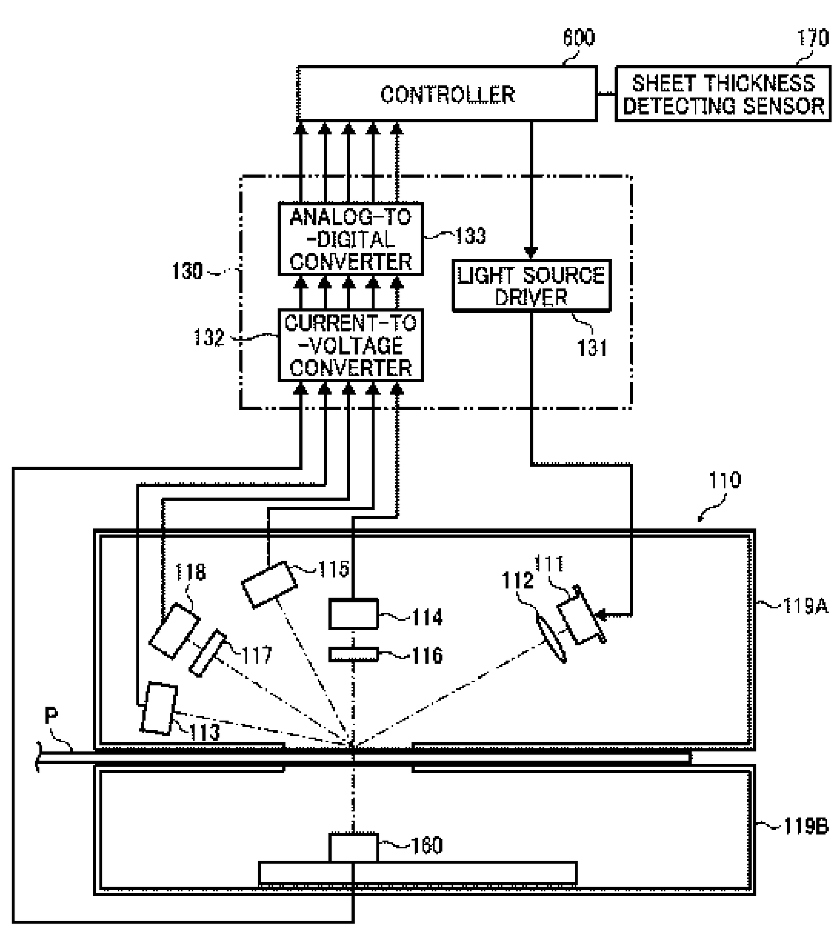
Primary Examiner — Tri T Ton
(74) *Attorney, Agent, or Firm* — Harness, Dickey & Pierce, P.L.C.

(57) **ABSTRACT**

A sheet discriminator, which can be included in an image forming apparatus, includes an optical information detector, a sheet distinguisher, and a sheet thickness detector. The optical information detector includes a light emitter to emit light to a recording medium and a light receiver to receive the light and detects information of the recording medium. The sheet distinguisher distinguishes a type of the recording medium based on the information detected by the optical information detector. The sheet thickness detector includes a displacement gauge to sandwich the recording medium with an opposing member disposed facing the displacement gauge and to move from an initial position thereof and a displacement detector to detect an amount of displacement of the displacement gauge. The sheet thickness detector detects a thickness of the recording medium based on detection results obtained by the displacement detector.

20 Claims, 22 Drawing Sheets



(51) **Int. Cl.**

G01N 21/59	(2006.01)
G01B 5/00	(2006.01)
G01B 5/24	(2006.01)
G01N 21/21	(2006.01)
G01N 21/47	(2006.01)

(52) **U.S. Cl.**
CPC ***G01N 21/55*** (2013.01); ***G01N 21/59*** (2013.01); *G01N 21/21* (2013.01); *G01N 21/474* (2013.01); *G01N 2021/556* (2013.01); *G01N 2021/558* (2013.01); *G01N 2201/0612* (2013.01); *G01N 2201/0683* (2013.01); *G03G 2215/00738* (2013.01); *G03G 2215/00751* (2013.01)

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FIG. 1

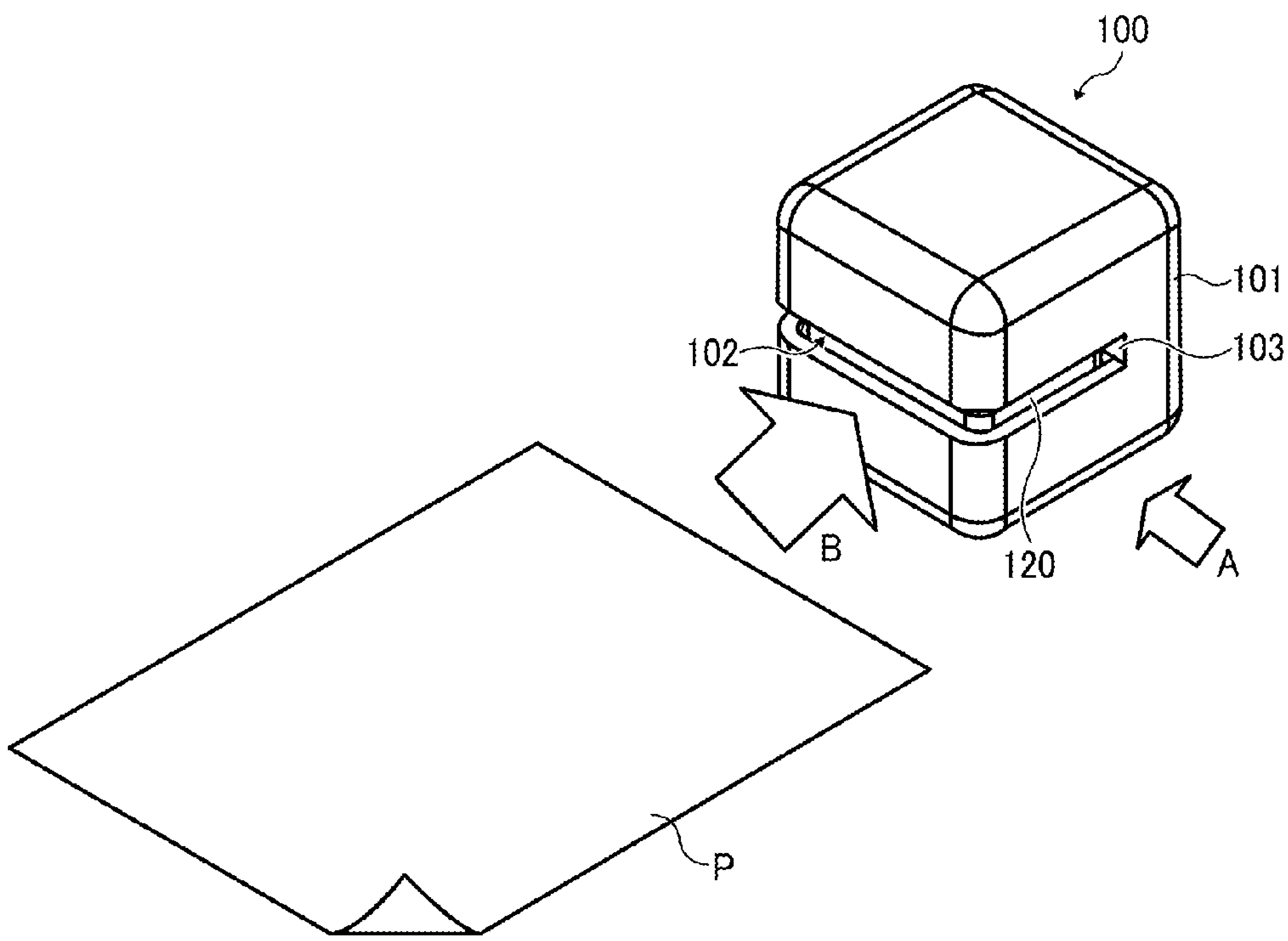


FIG. 2A

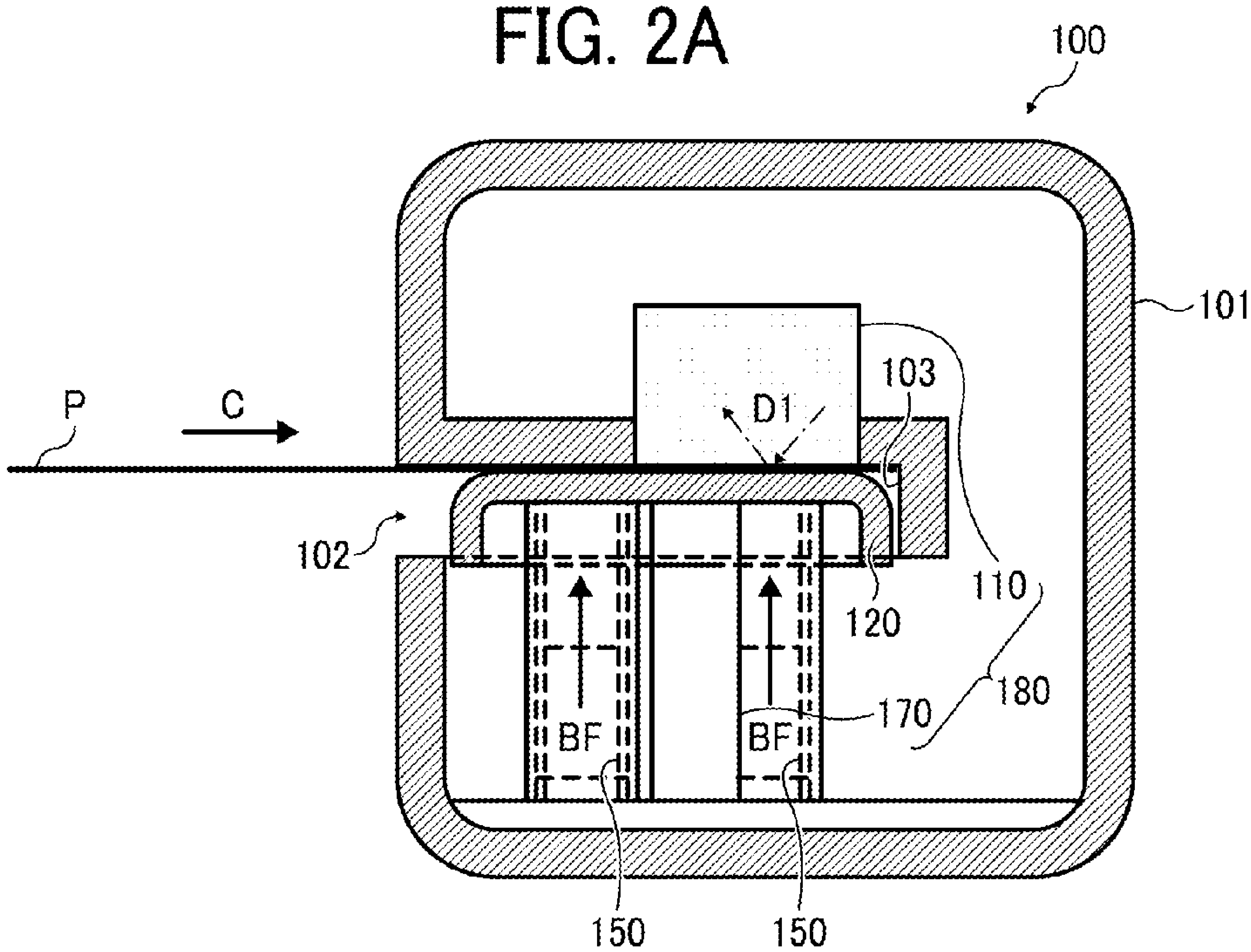

100
101
103
P
C
D1
102
110
120
180
170
BF
BF
150
150

FIG. 2B

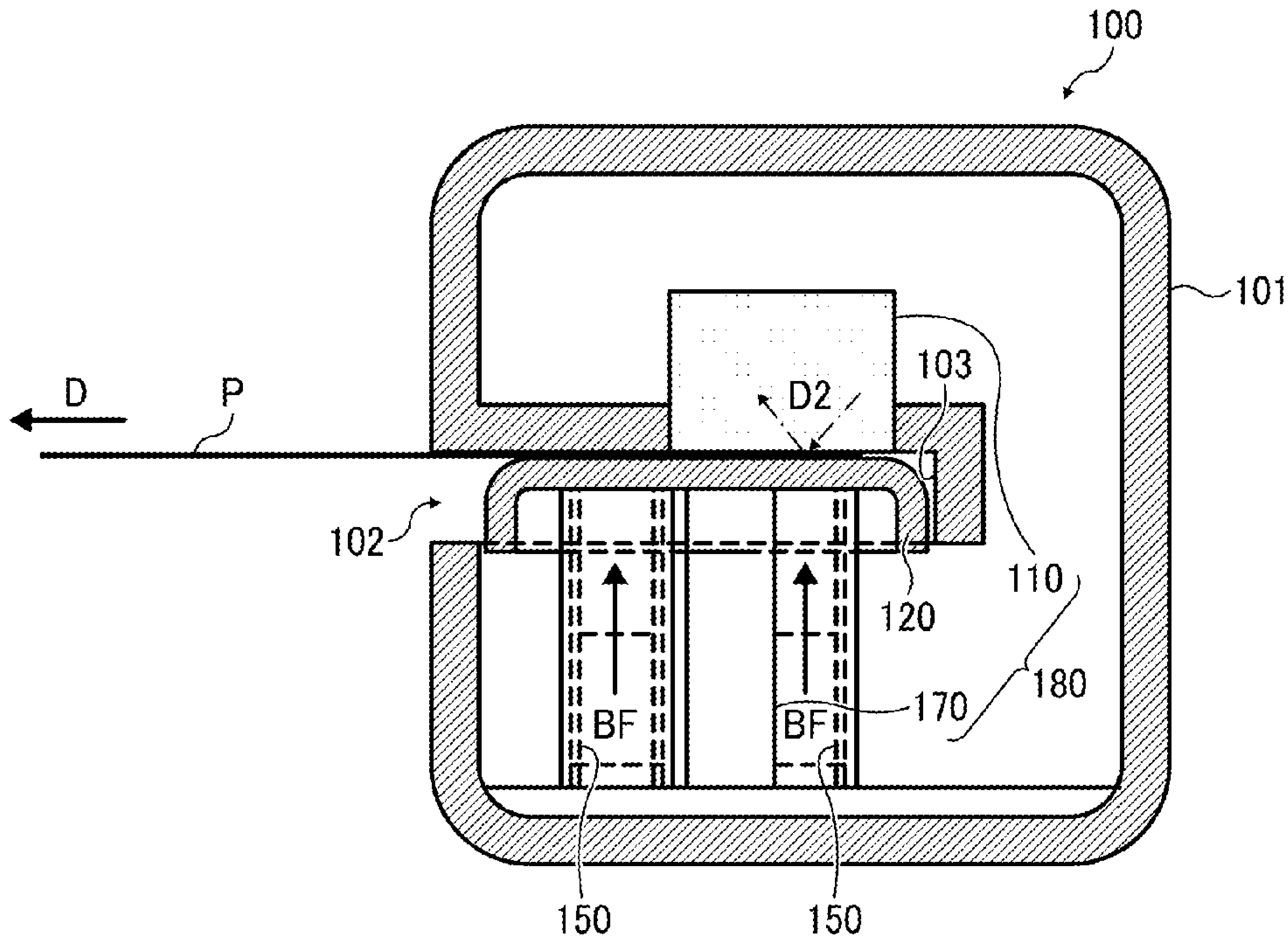

100
101
103
D
P
D2
102
110
120
180
170
BF
BF
150
150

FIG. 3

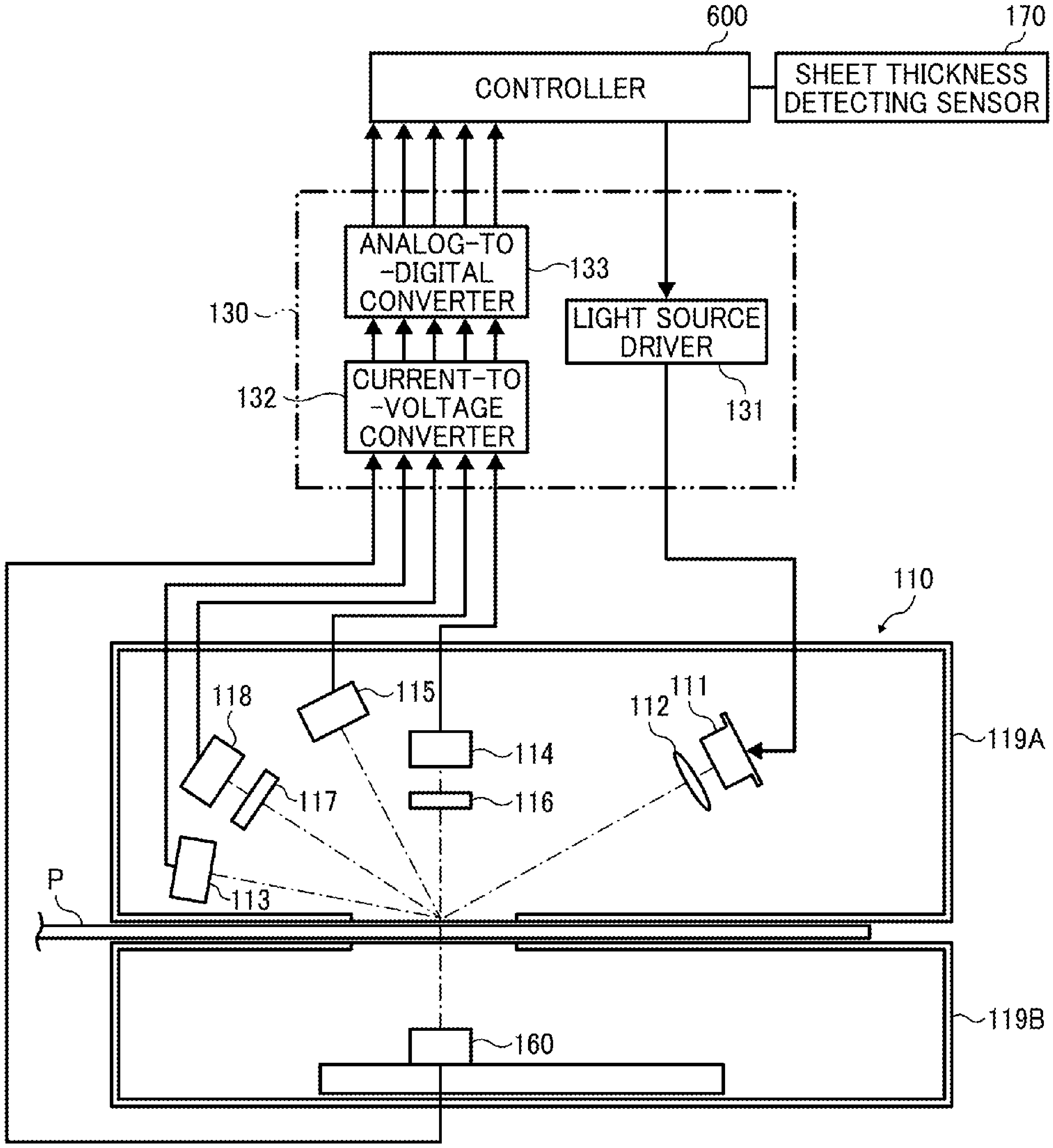

600
170
CONTROLLER
SHEET THICKNESS DETECTING SENSOR
ANALOG-TO -DIGITAL CONVERTER
133
130
LIGHT SOURCE DRIVER
132
CURRENT-TO -VOLTAGE CONVERTER
131
110
118
115
111
112
114
119A
117
116
P
113
119B
160

FIG. 4

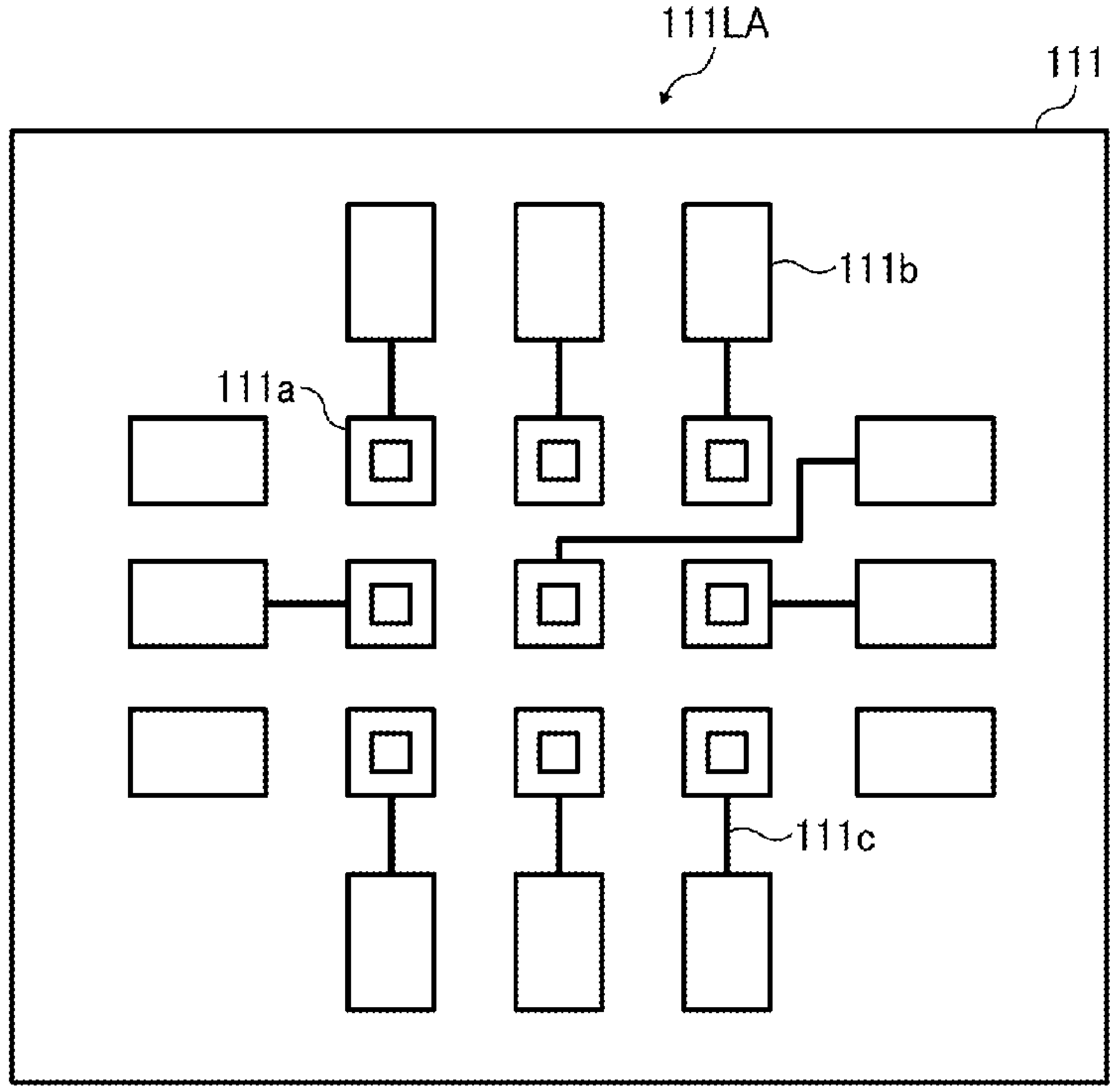

111LA
111
111b
111a
111c

FIG. 5

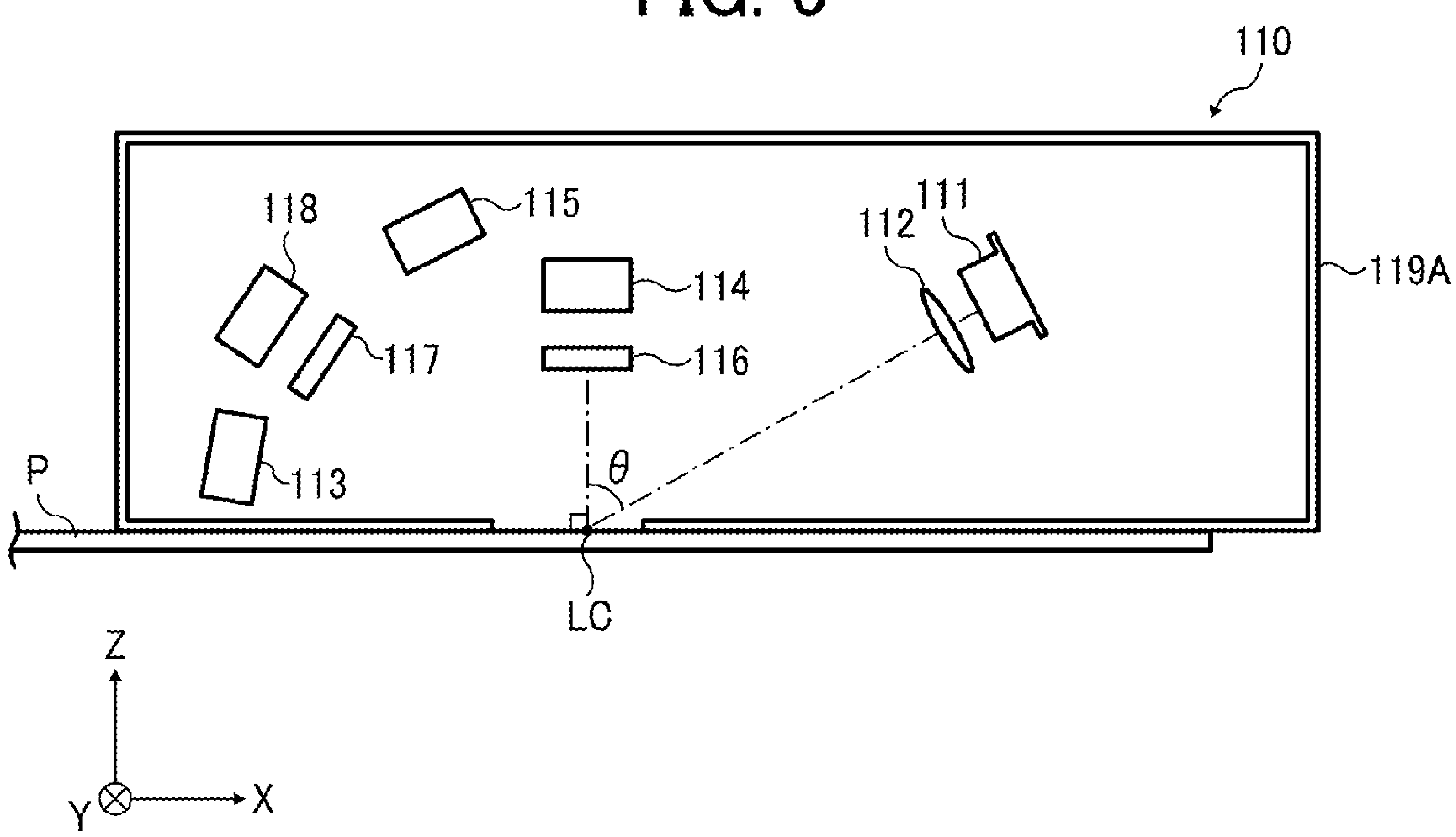

110
118
115
111
112
114
119A
117
116
θ
P
113
LC
Z
Y
X

FIG. 6

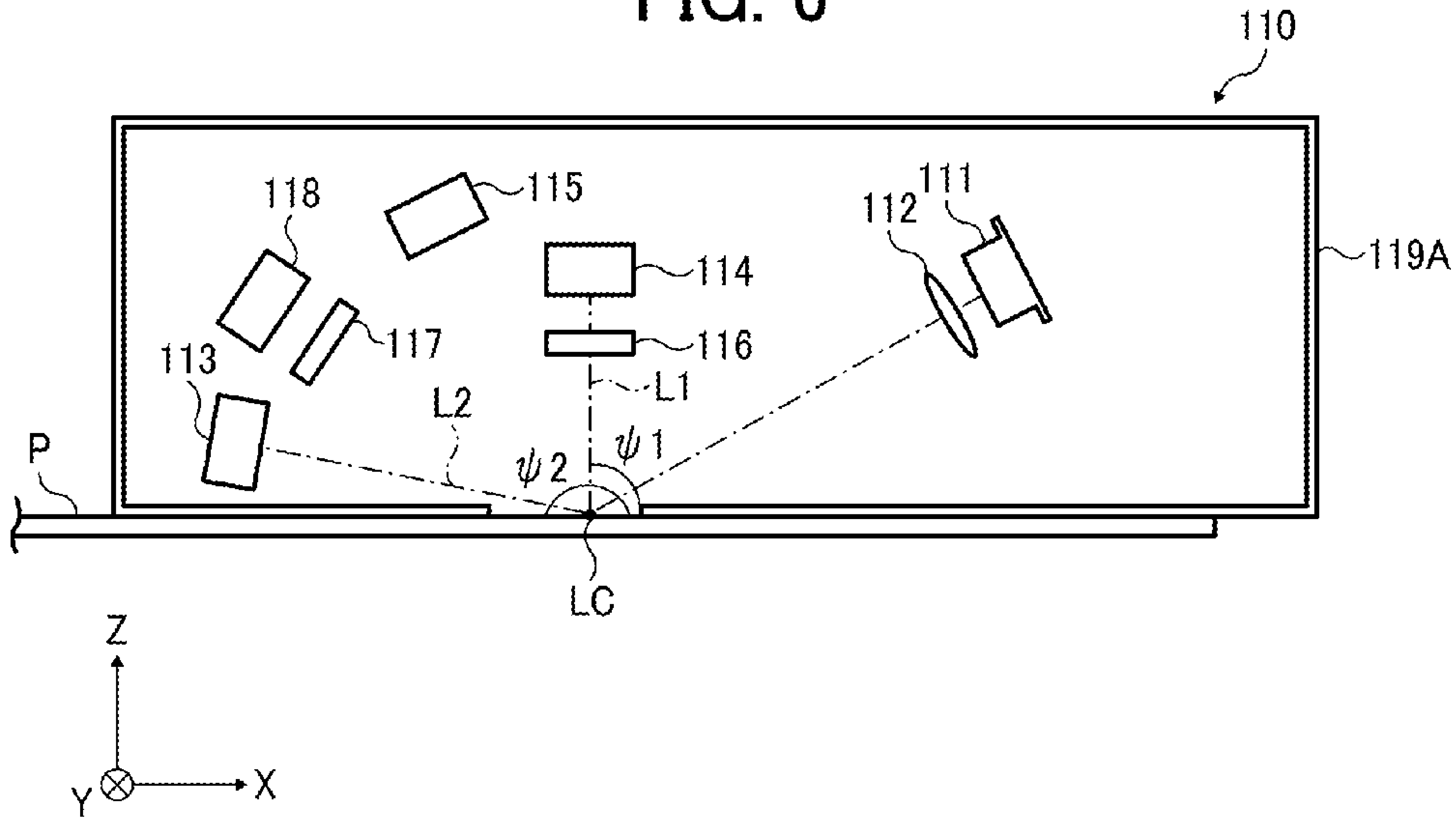


FIG. 7A

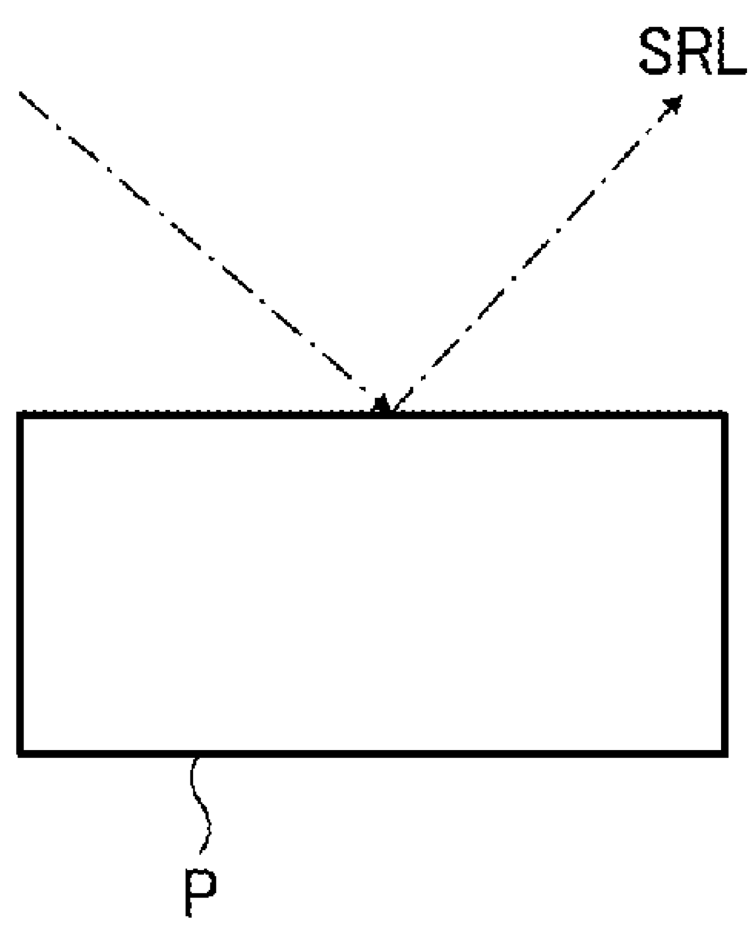


FIG. 7B

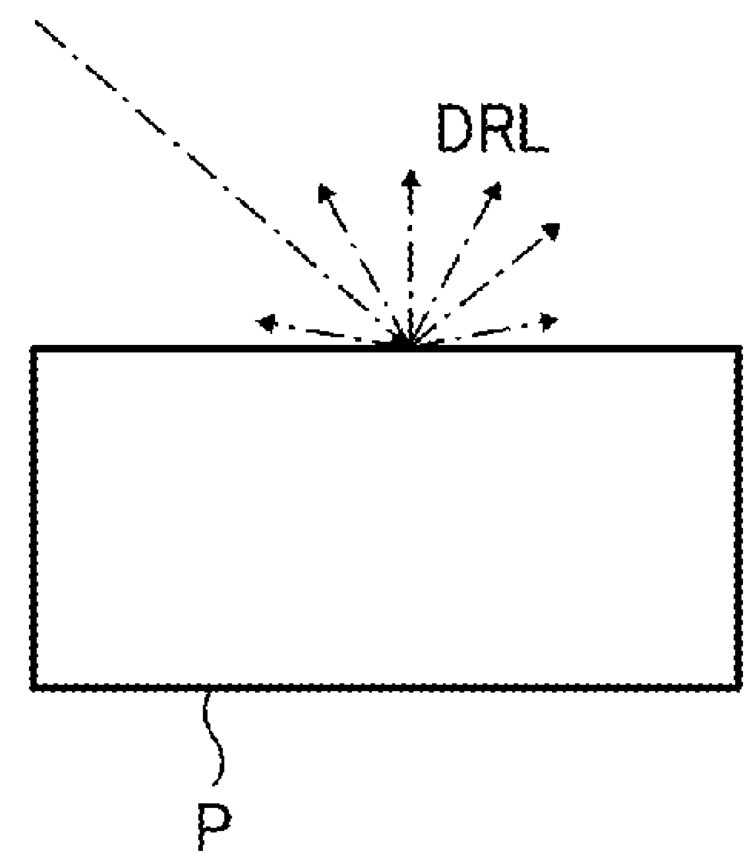


FIG. 7C

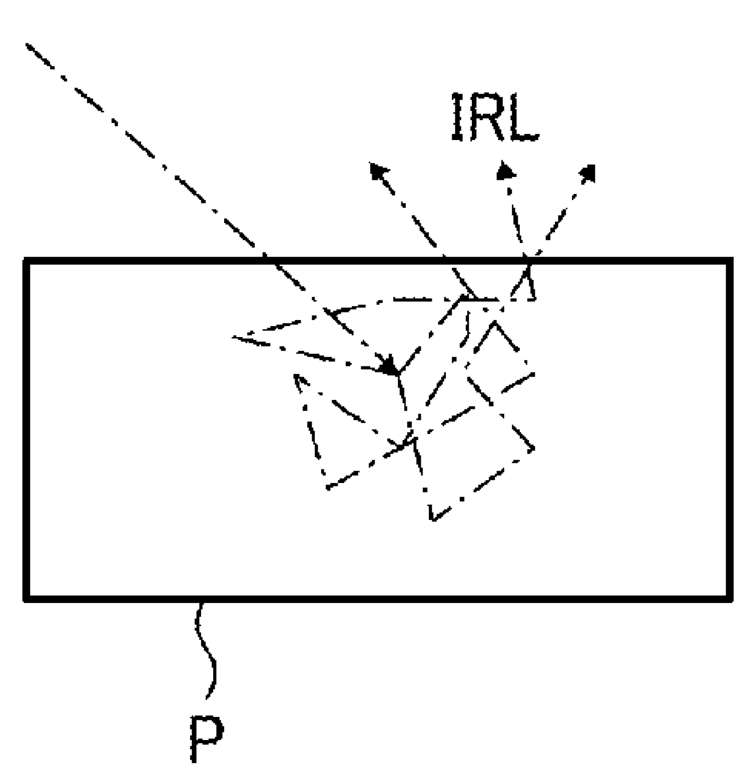


FIG. 8

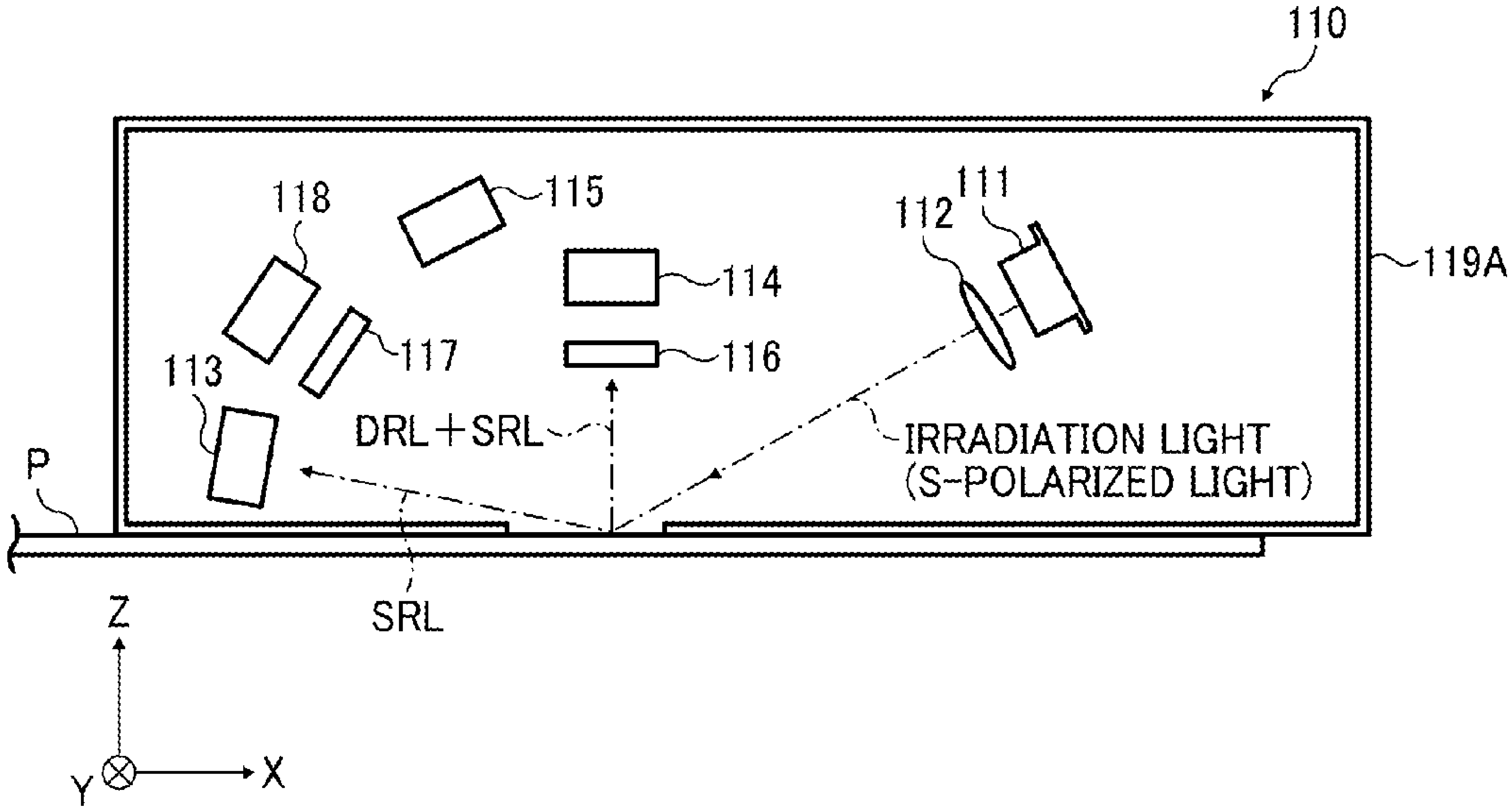

110
118
115
114
116
117
113
112
111
119A
DRL+SRL
IRRADIATION LIGHT
(S-POLARIZED LIGHT)
P
SRL
Z
Y
X

FIG. 9

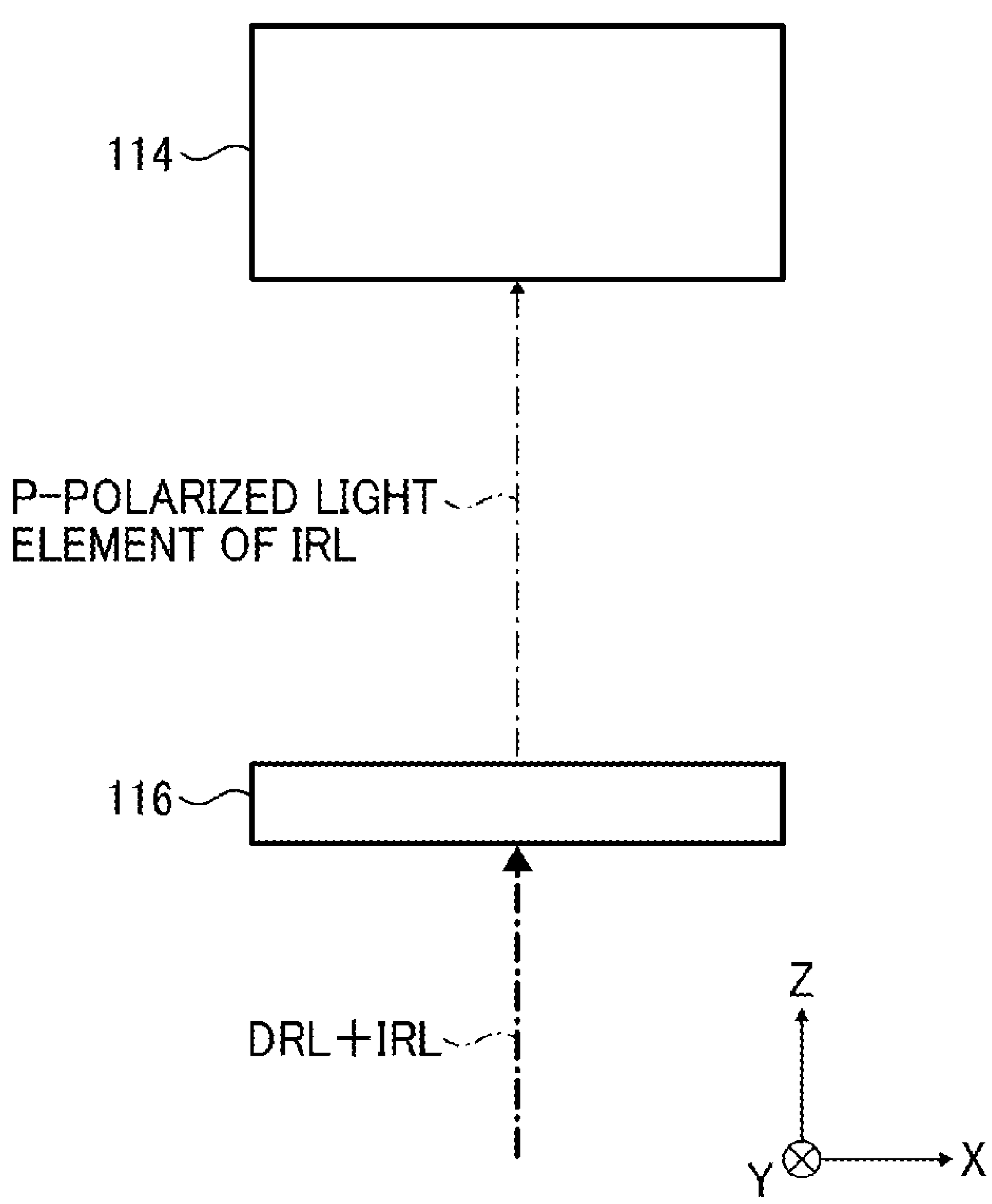

114
P-POLARIZED LIGHT
ELEMENT OF IRL
116
DRL+IRL
Z
Y
X

FIG. 10

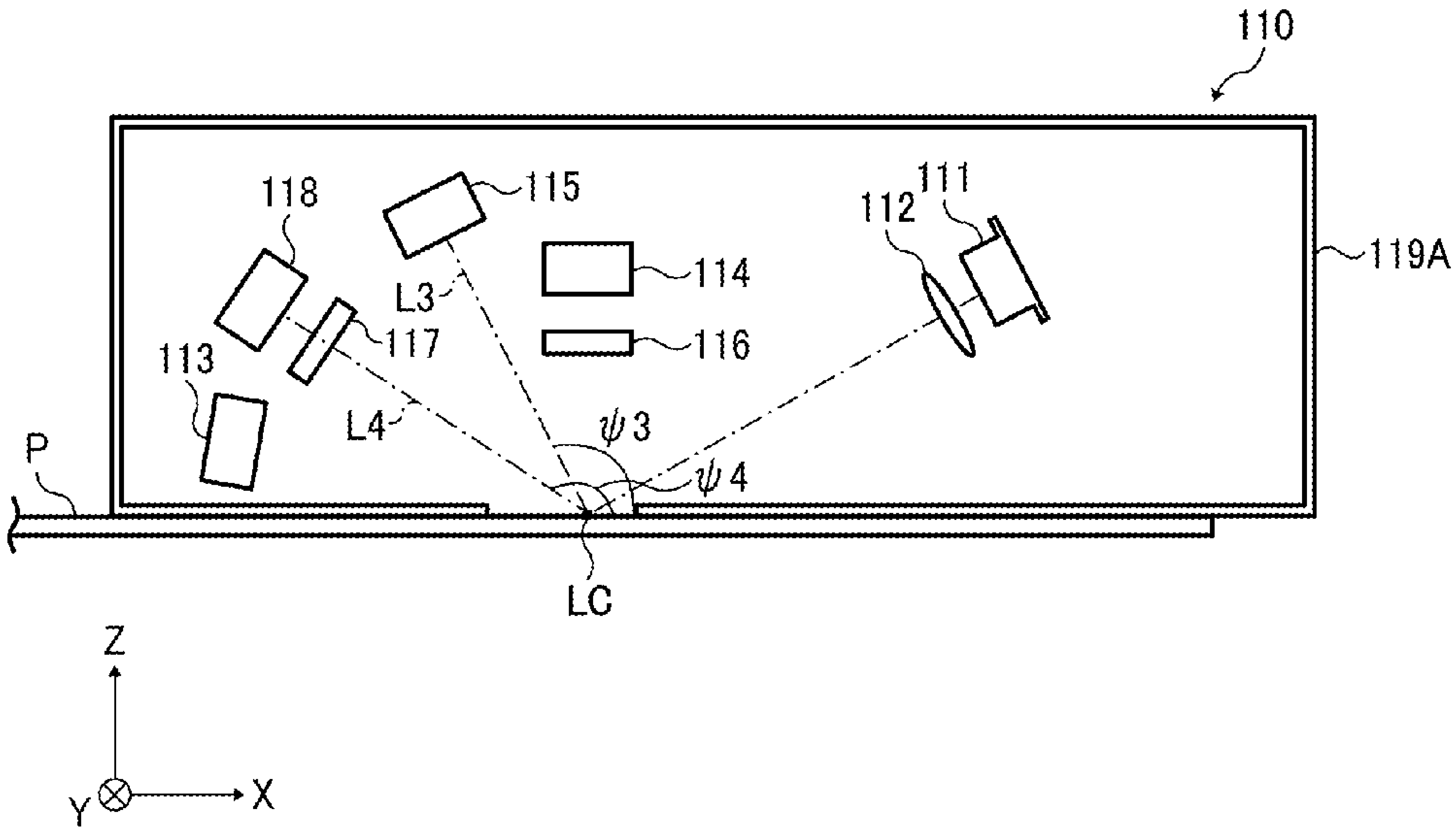
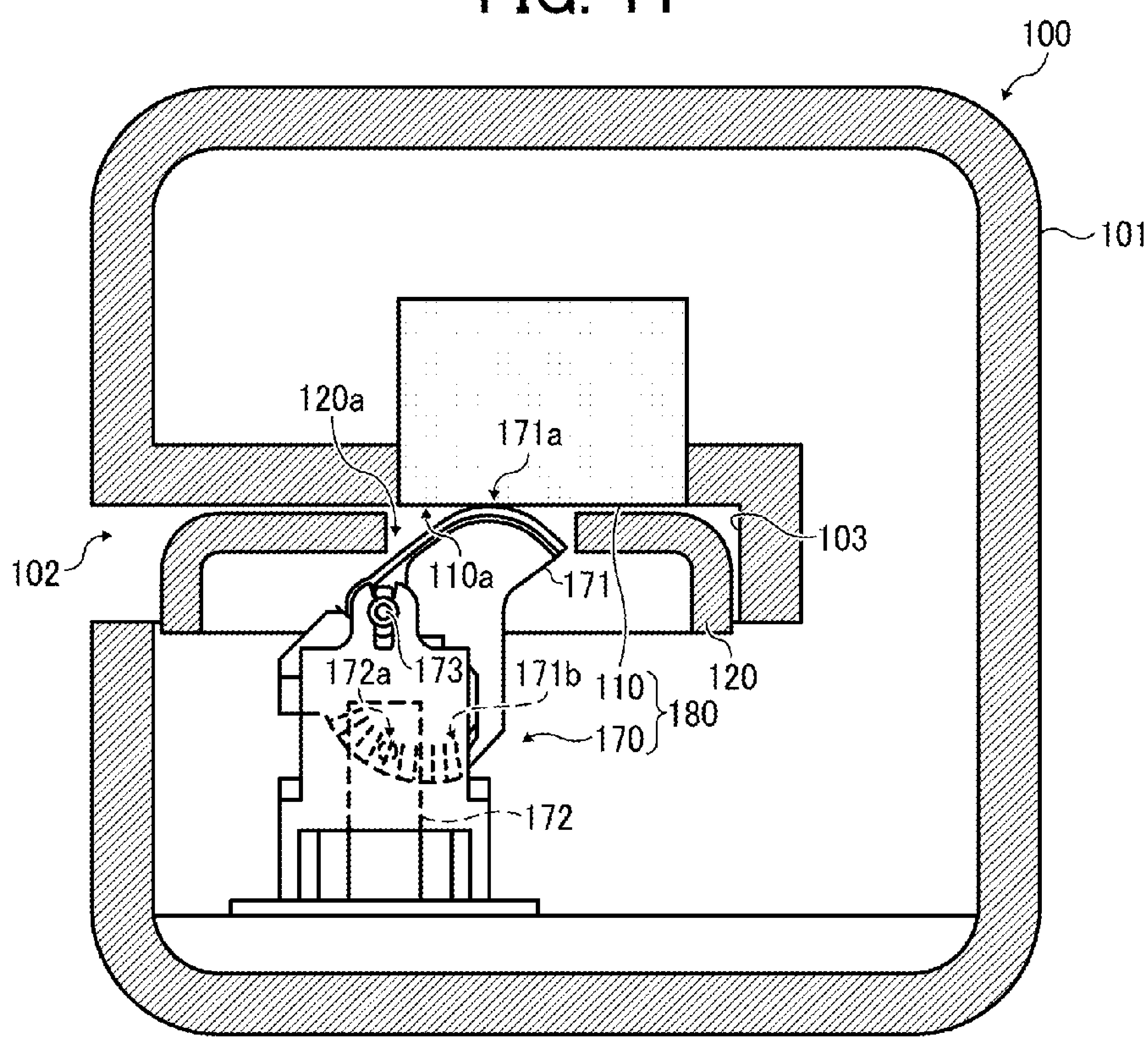

110
118
115
114
116
112
111
119A
L3
117
113
L4
ψ3
ψ4
P
LC
Z
Y
X

FIG. 11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172a
173
171b
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180
170
172

FIG. 12

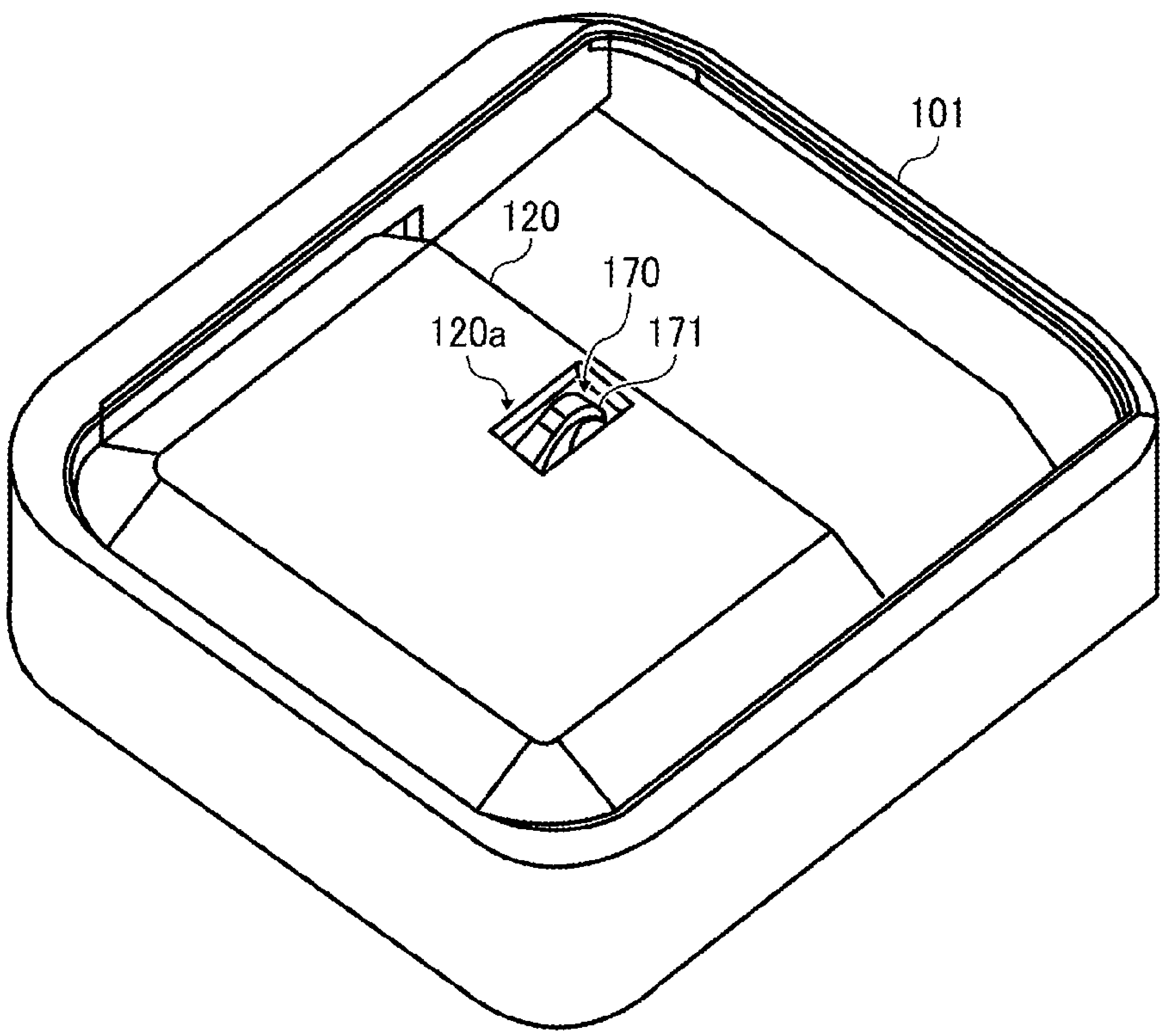


FIG. 13A

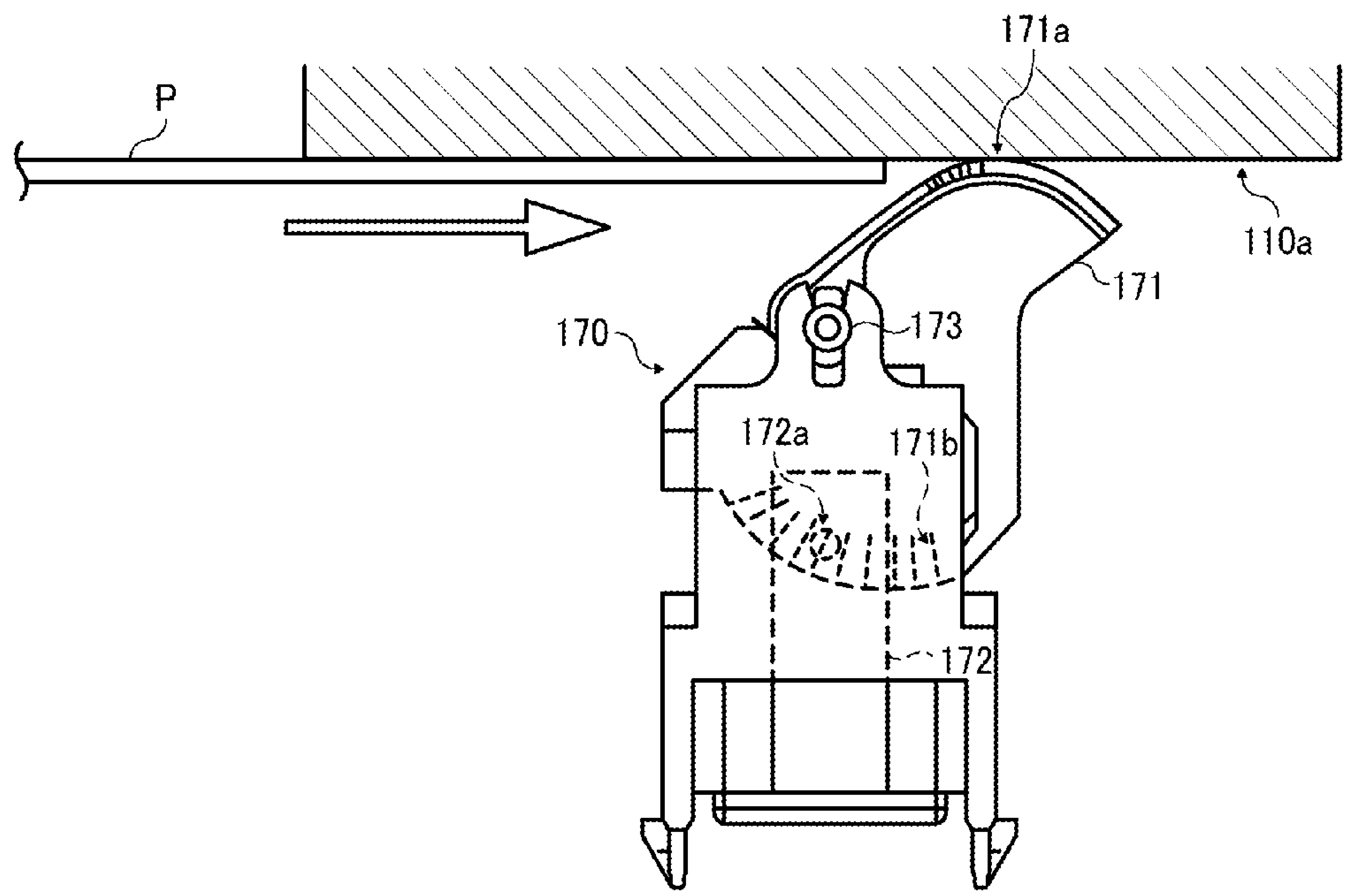


FIG. 13B

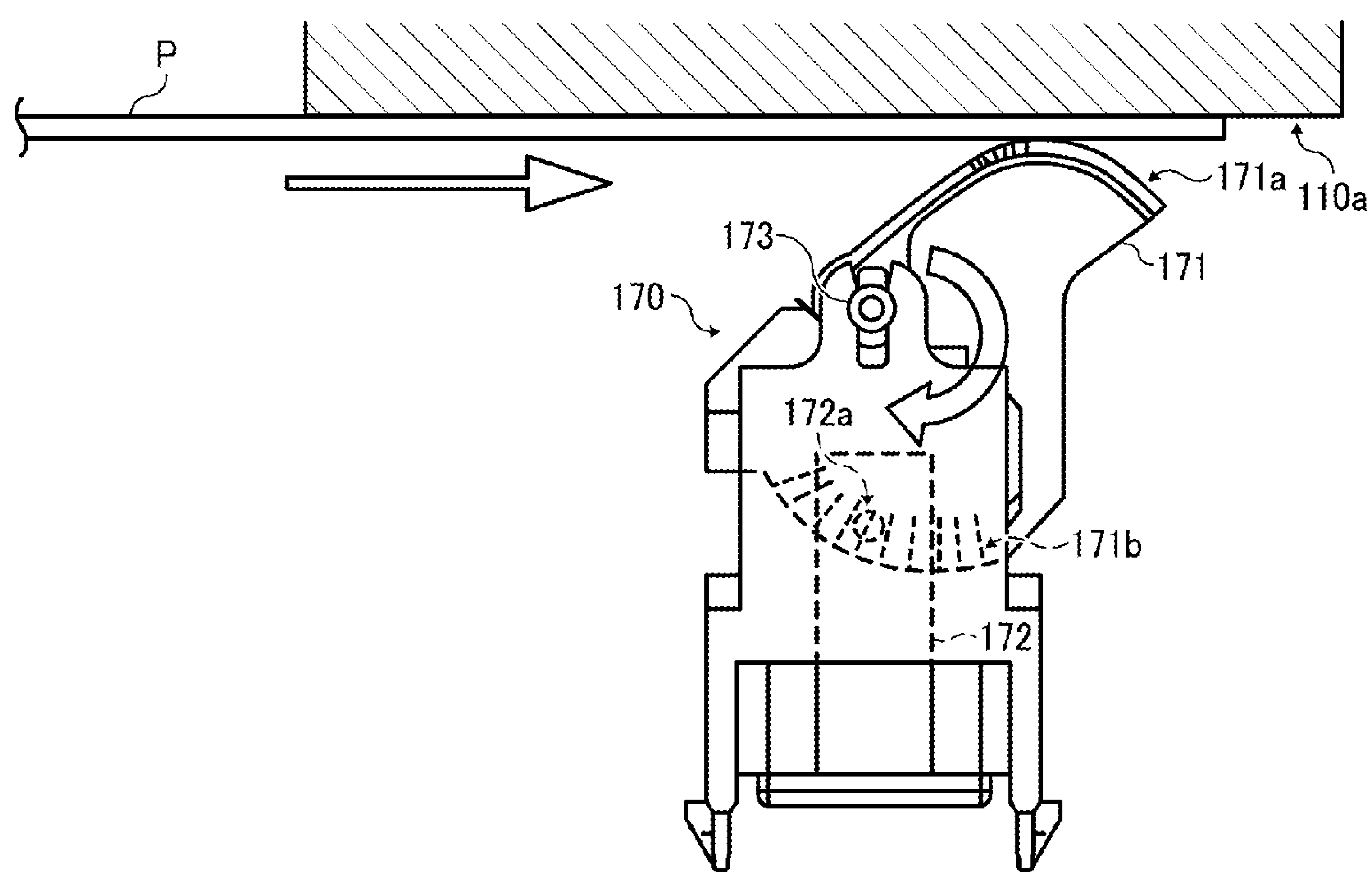


FIG. 14

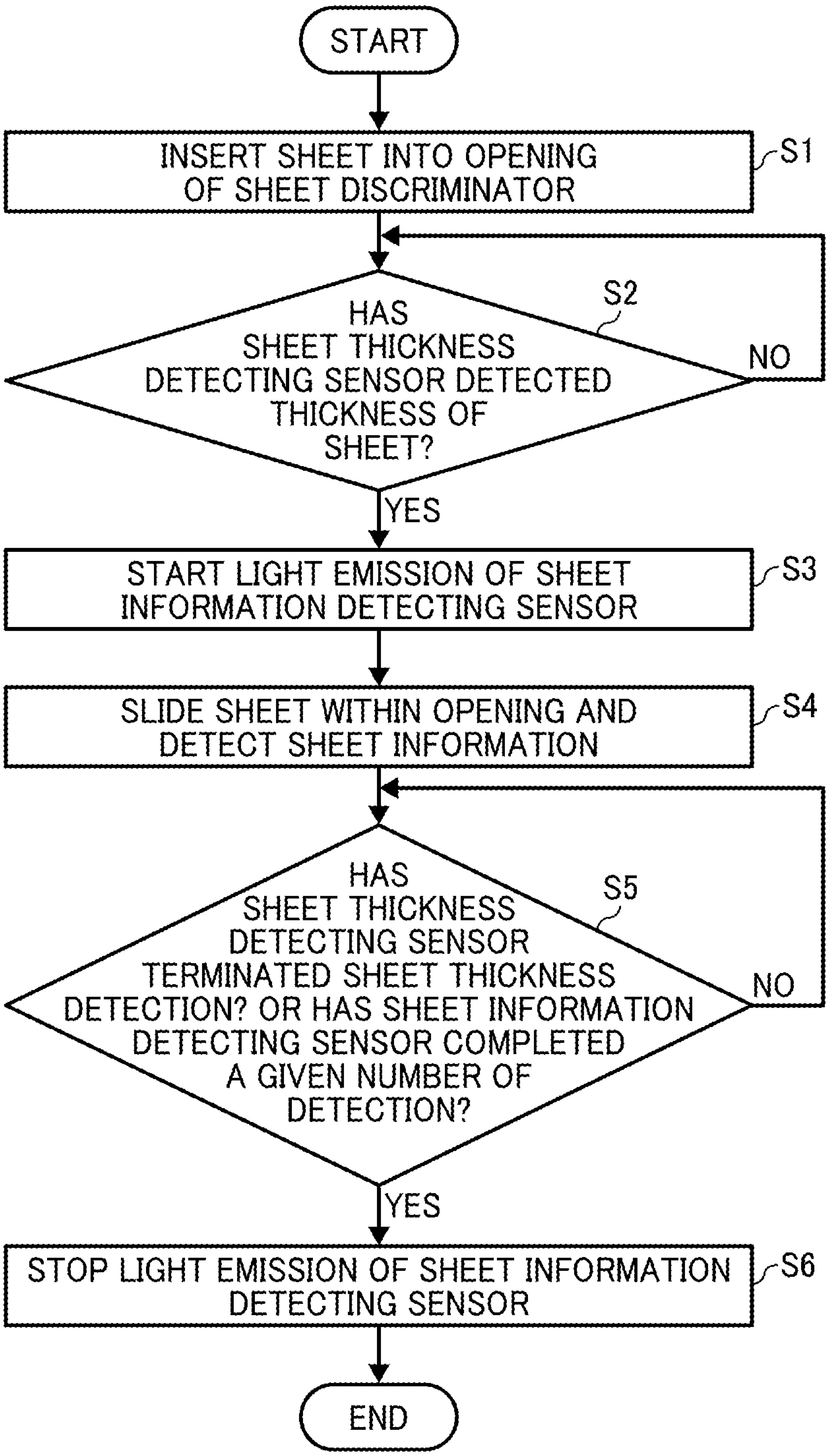

START
INSERT SHEET INTO OPENING OF SHEET DISCRIMINATOR
S1
HAS SHEET THICKNESS DETECTING SENSOR DETECTED THICKNESS OF SHEET?
S2
NO
YES
START LIGHT EMISSION OF SHEET INFORMATION DETECTING SENSOR
S3
SLIDE SHEET WITHIN OPENING AND DETECT SHEET INFORMATION
S4
HAS SHEET THICKNESS DETECTING SENSOR TERMINATED SHEET THICKNESS DETECTION? OR HAS SHEET INFORMATION DETECTING SENSOR COMPLETED A GIVEN NUMBER OF DETECTION?
S5
NO
YES
STOP LIGHT EMISSION OF SHEET INFORMATION DETECTING SENSOR
S6
END

FIG. 15A

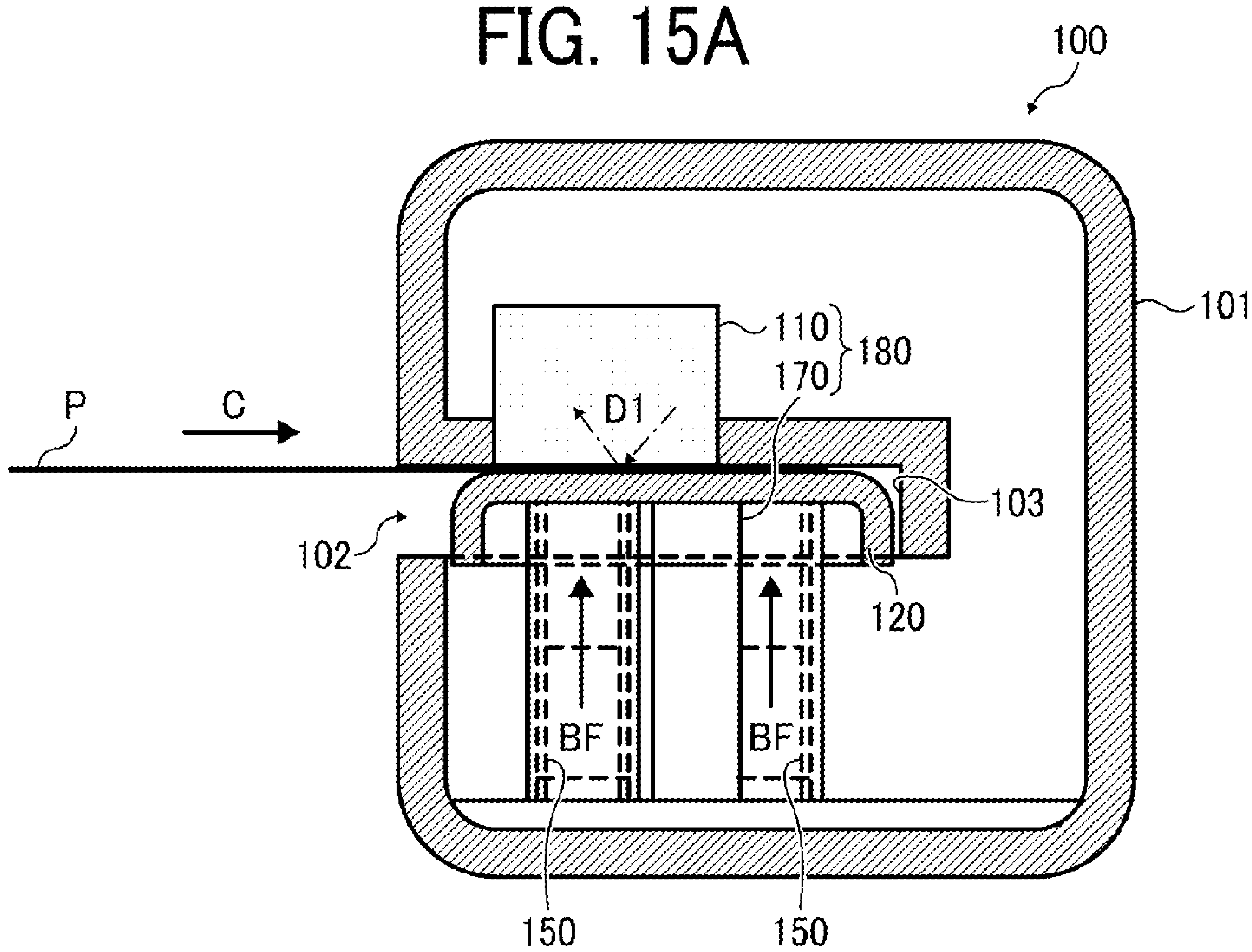


FIG. 15B

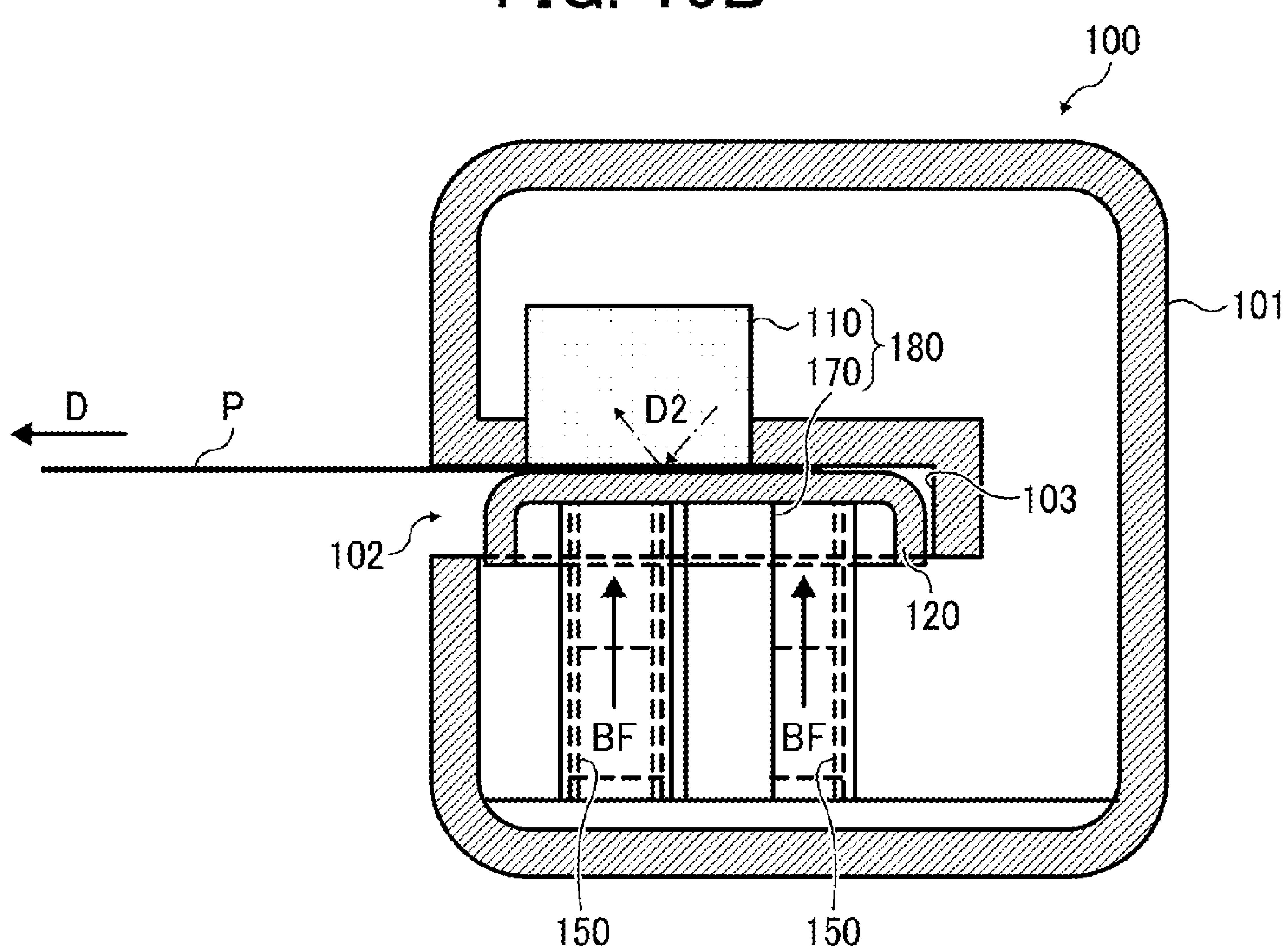


FIG. 16

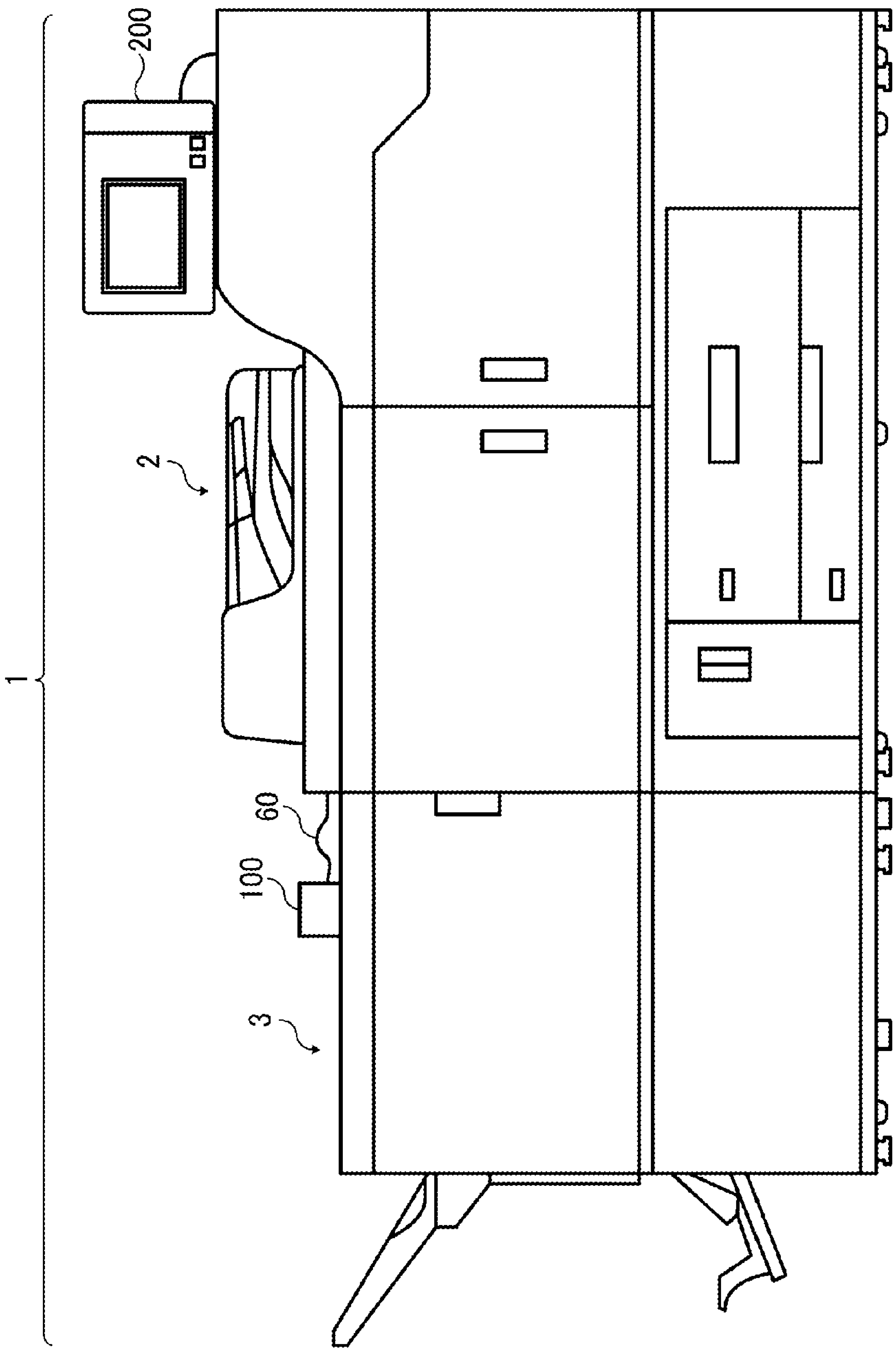
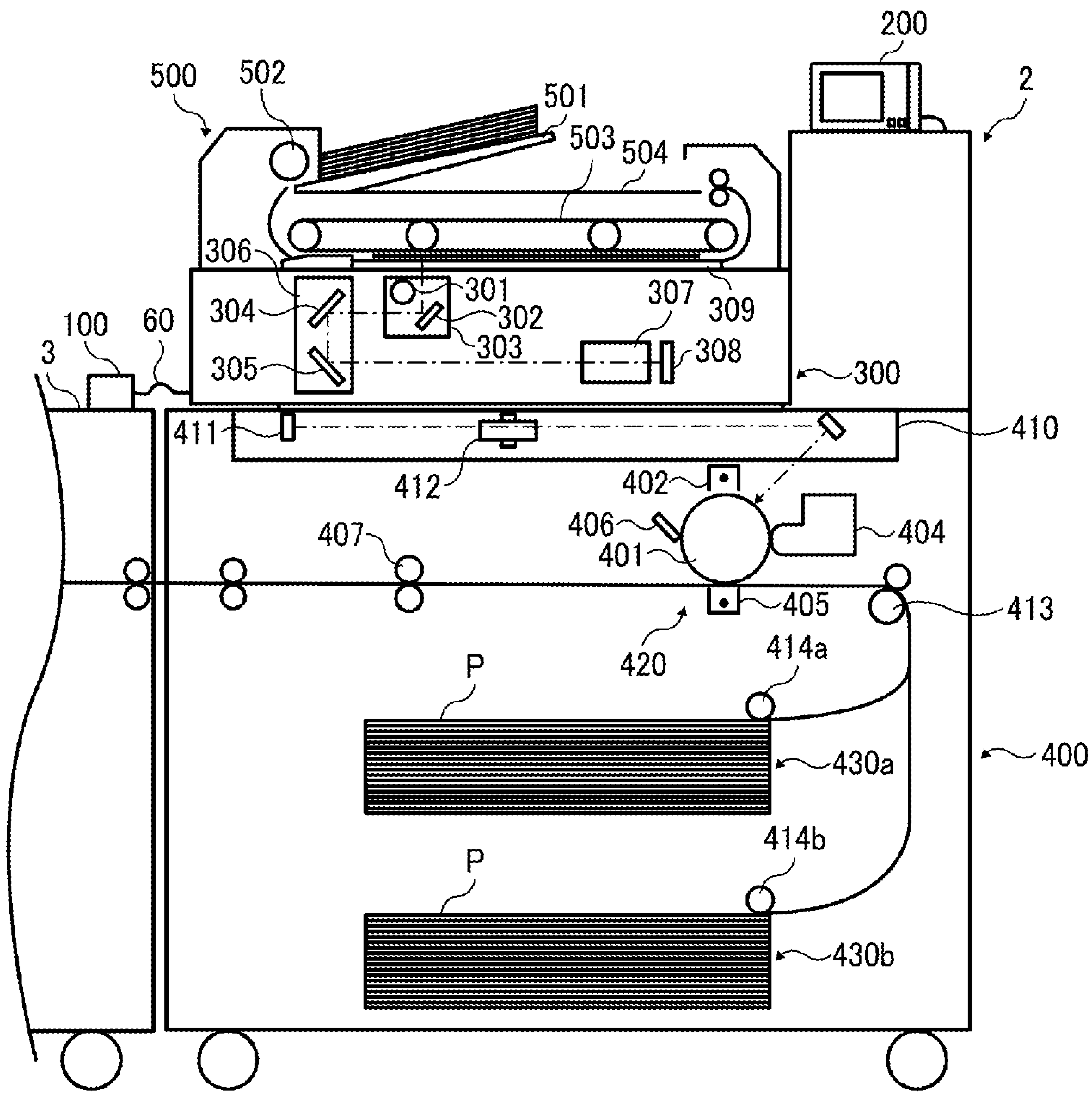


FIG. 17



200
500
502
501
503
504
2
306
301
307
309
304
302
308
100
60
303
3
305
300
411
410
412
402
406
404
407
401
405
413
420
414a
P
430a
400
414b
P
430b

FIG. 18

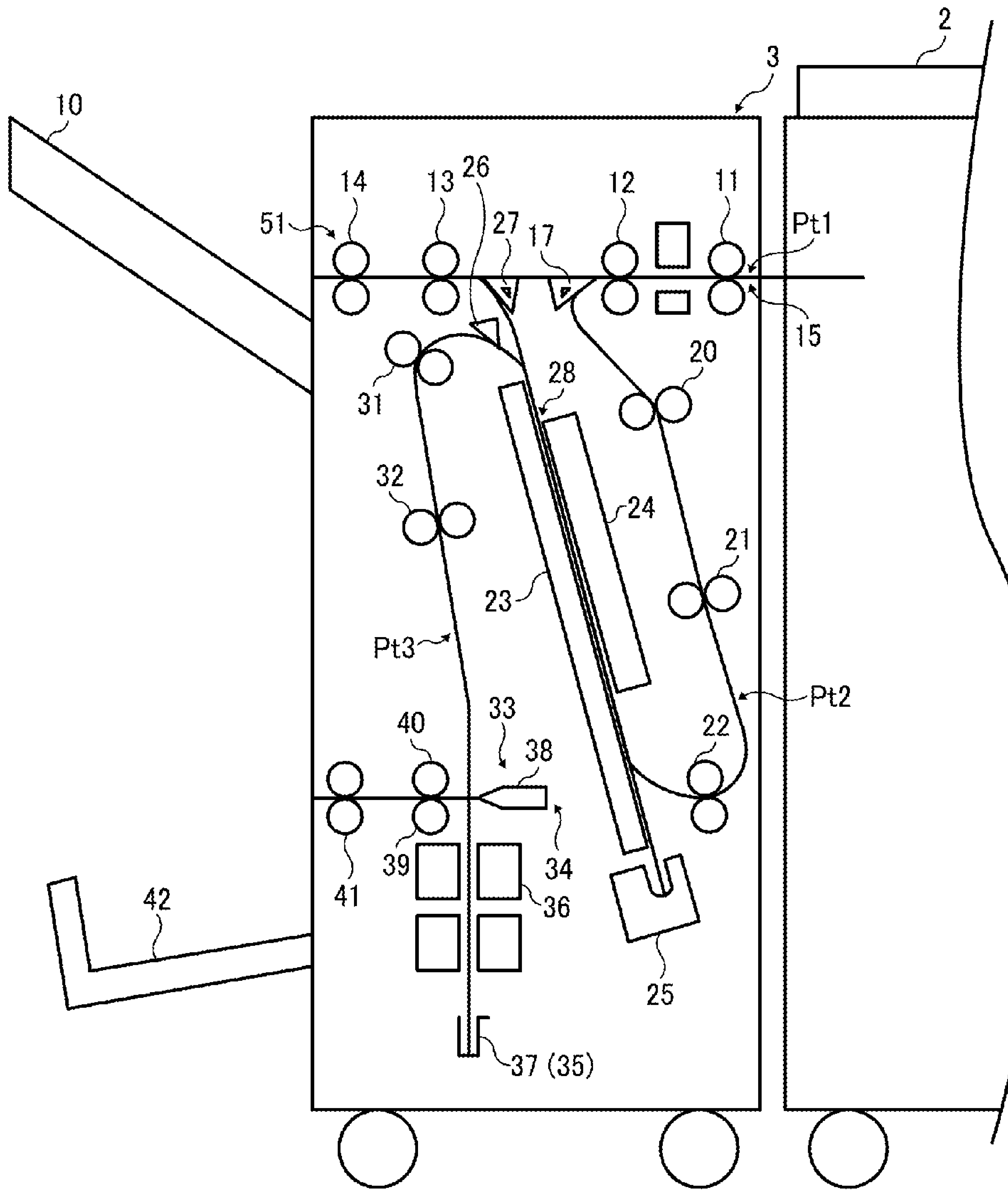

2
3
10
14
13
26
12
11
51
27
17
Pt1
15
20
31
28
24
32
21
23
Pt3
Pt2
33
40
38
22
34
39
41
36
42
25
37 (35)

FIG. 19

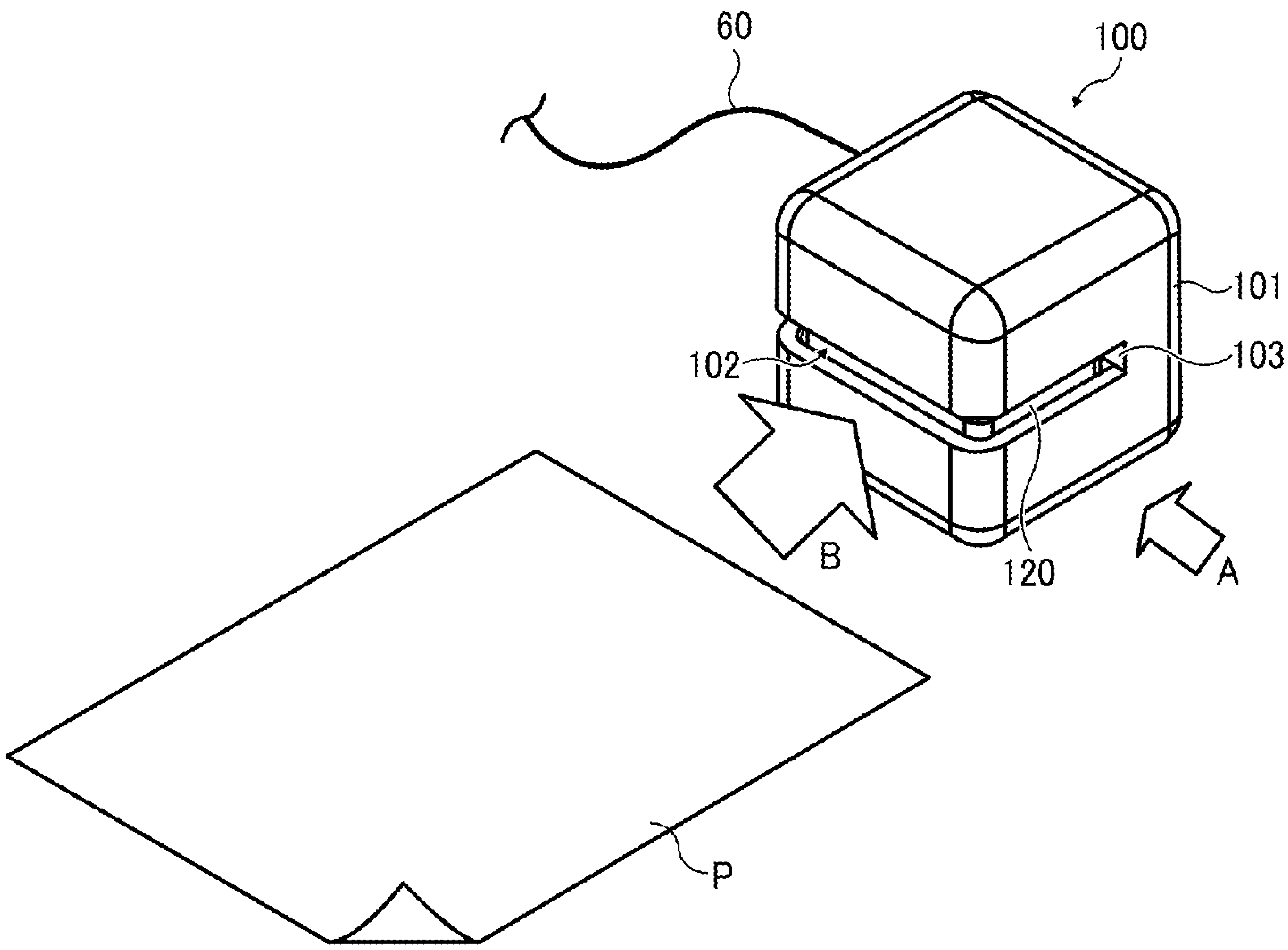


FIG. 20A

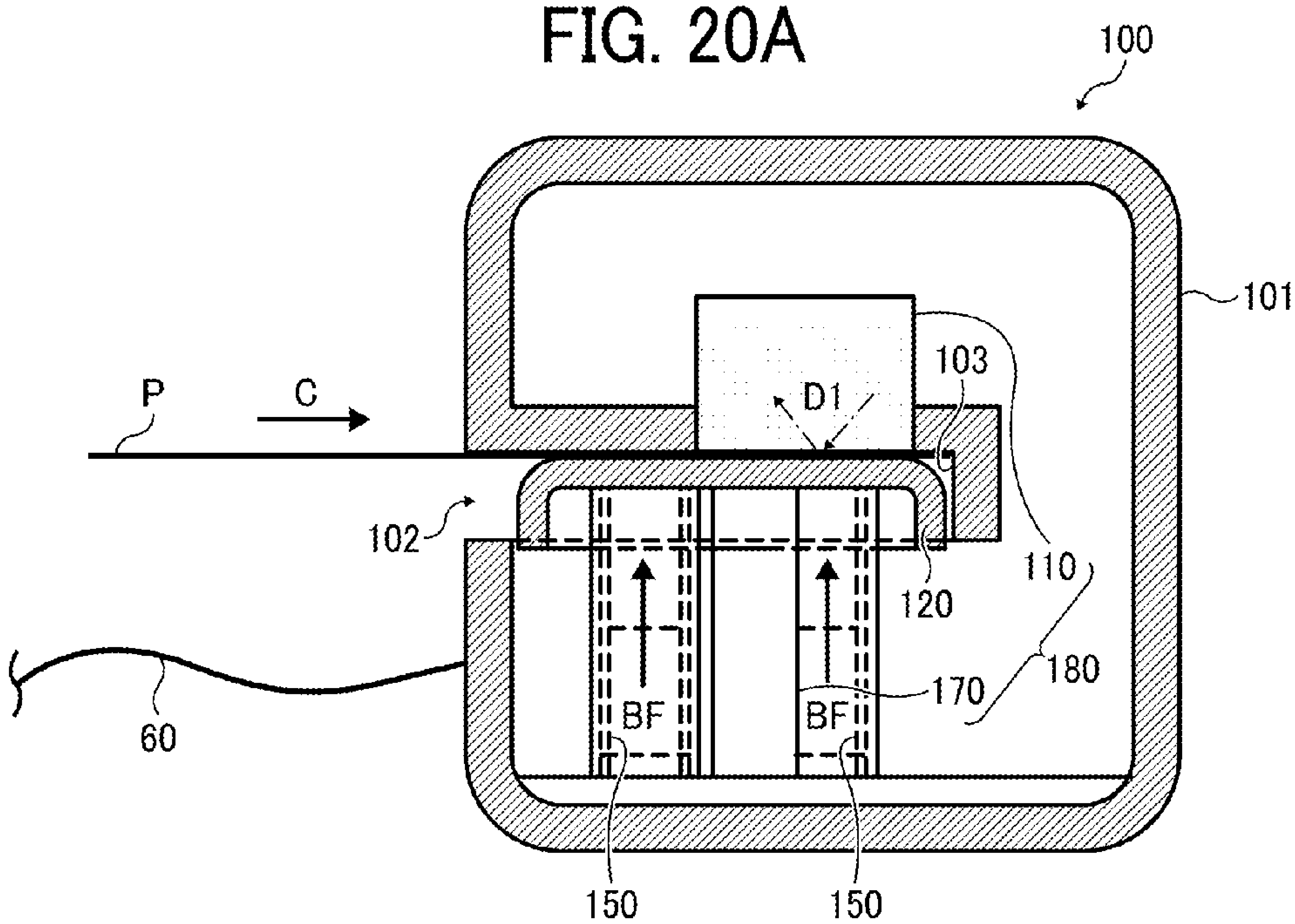


FIG. 20B

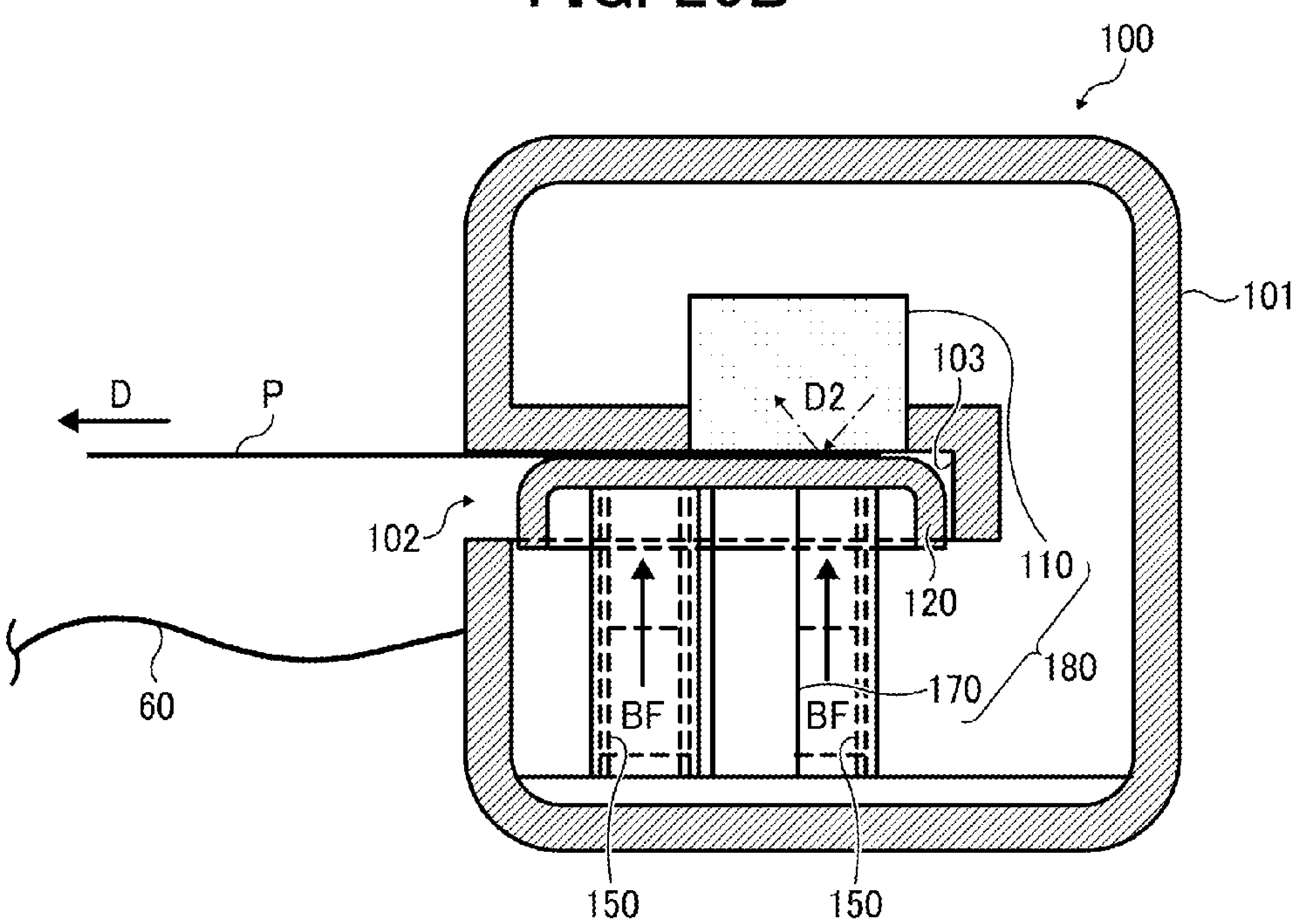


FIG. 21

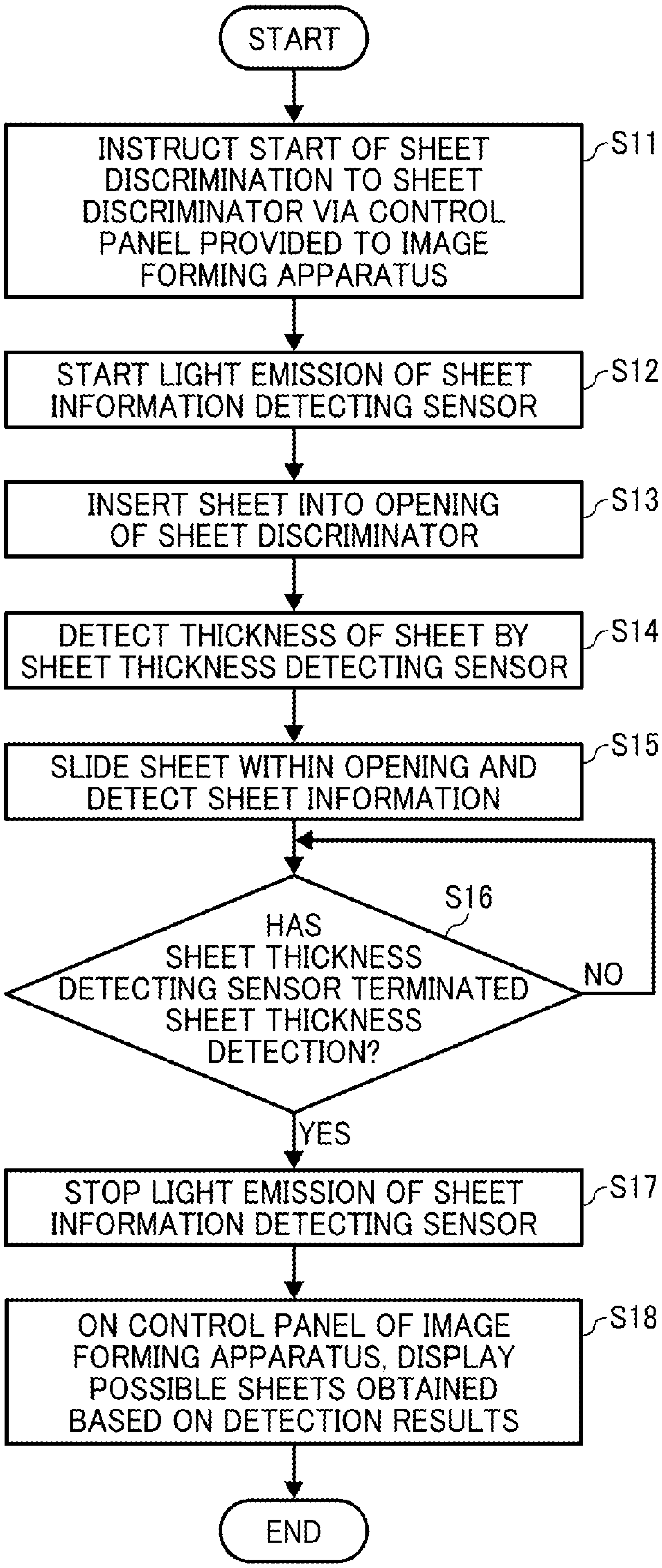

START
INSTRUCT START OF SHEET DISCRIMINATION TO SHEET DISCRIMINATOR VIA CONTROL PANEL PROVIDED TO IMAGE FORMING APPARATUS
S11
START LIGHT EMISSION OF SHEET INFORMATION DETECTING SENSOR
S12
INSERT SHEET INTO OPENING OF SHEET DISCRIMINATOR
S13
DETECT THICKNESS OF SHEET BY SHEET THICKNESS DETECTING SENSOR
S14
SLIDE SHEET WITHIN OPENING AND DETECT SHEET INFORMATION
S15
HAS SHEET THICKNESS DETECTING SENSOR TERMINATED SHEET THICKNESS DETECTION?
S16
NO
YES
STOP LIGHT EMISSION OF SHEET INFORMATION DETECTING SENSOR
S17
ON CONTROL PANEL OF IMAGE FORMING APPARATUS, DISPLAY POSSIBLE SHEETS OBTAINED BASED ON DETECTION RESULTS
S18
END

FIG. 22

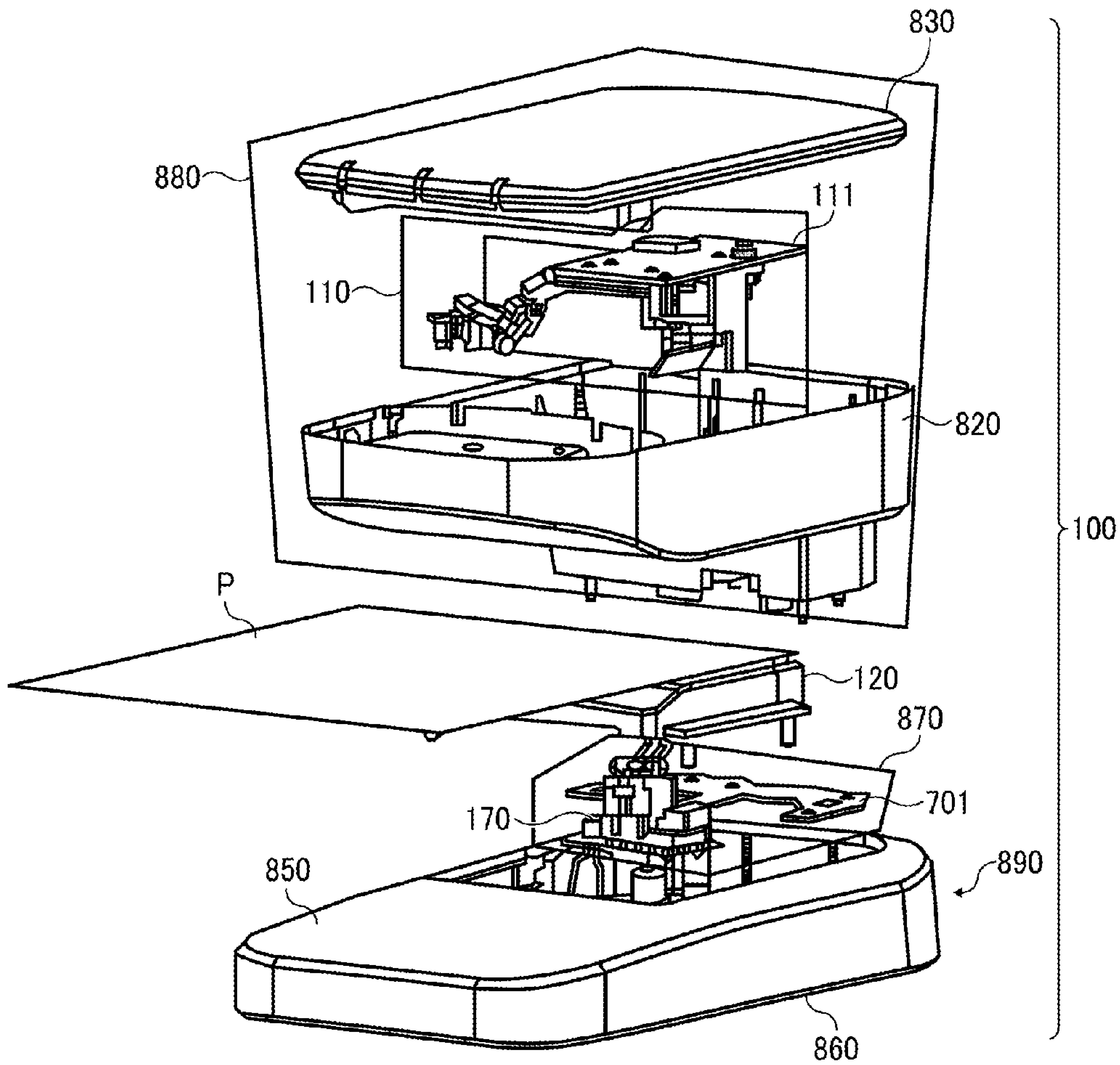


FIG. 23

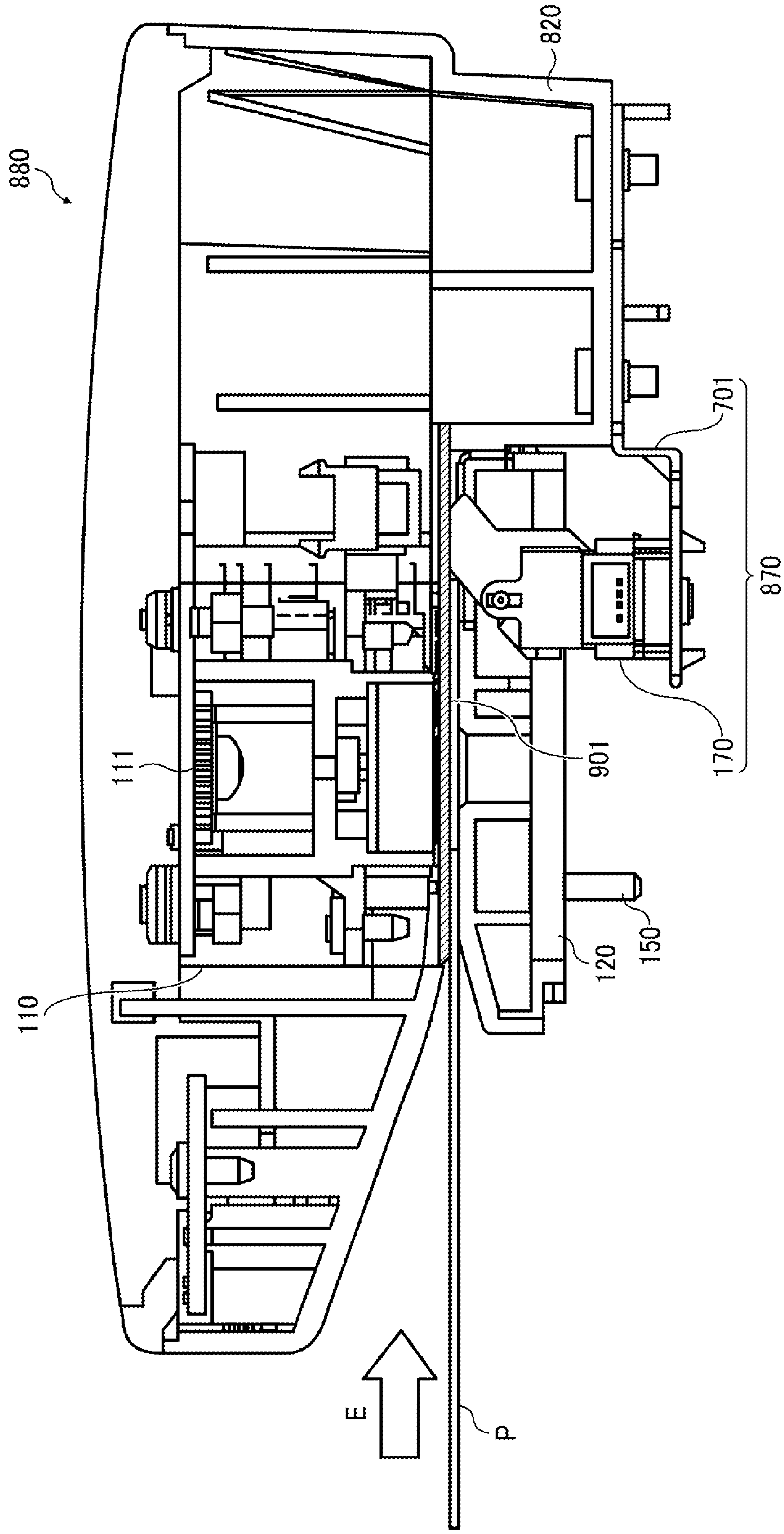


FIG. 24A

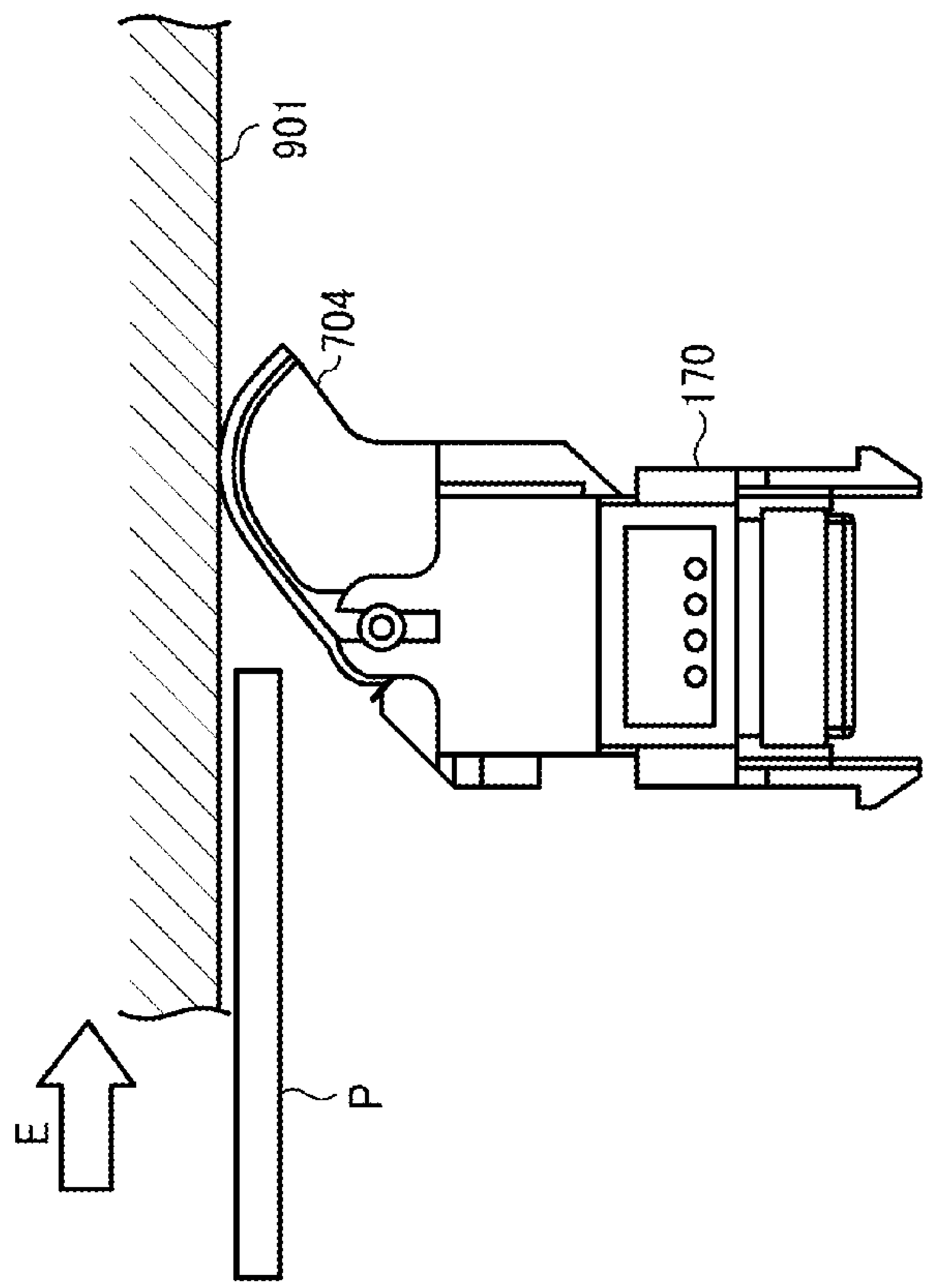


FIG. 24B

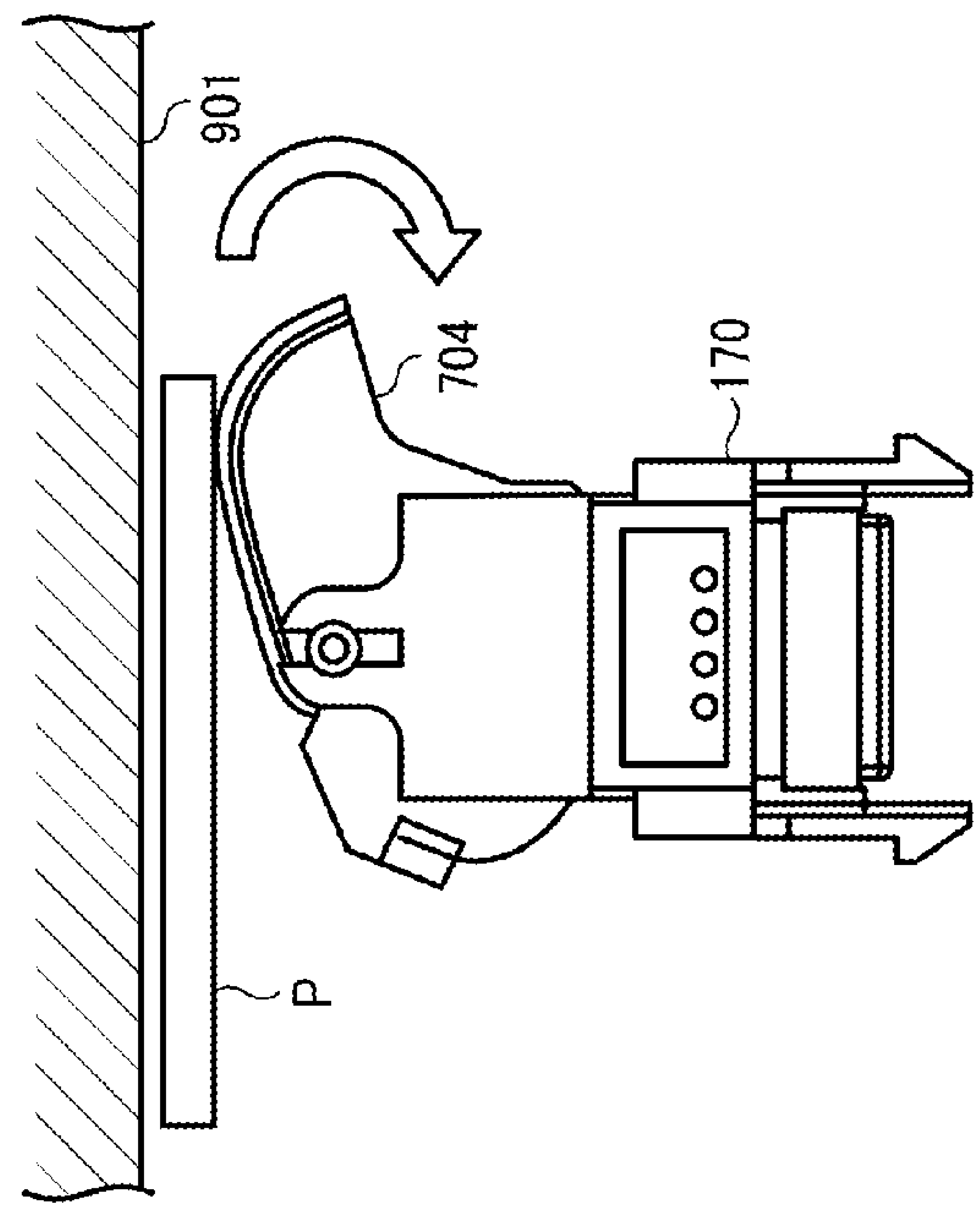


FIG. 25A

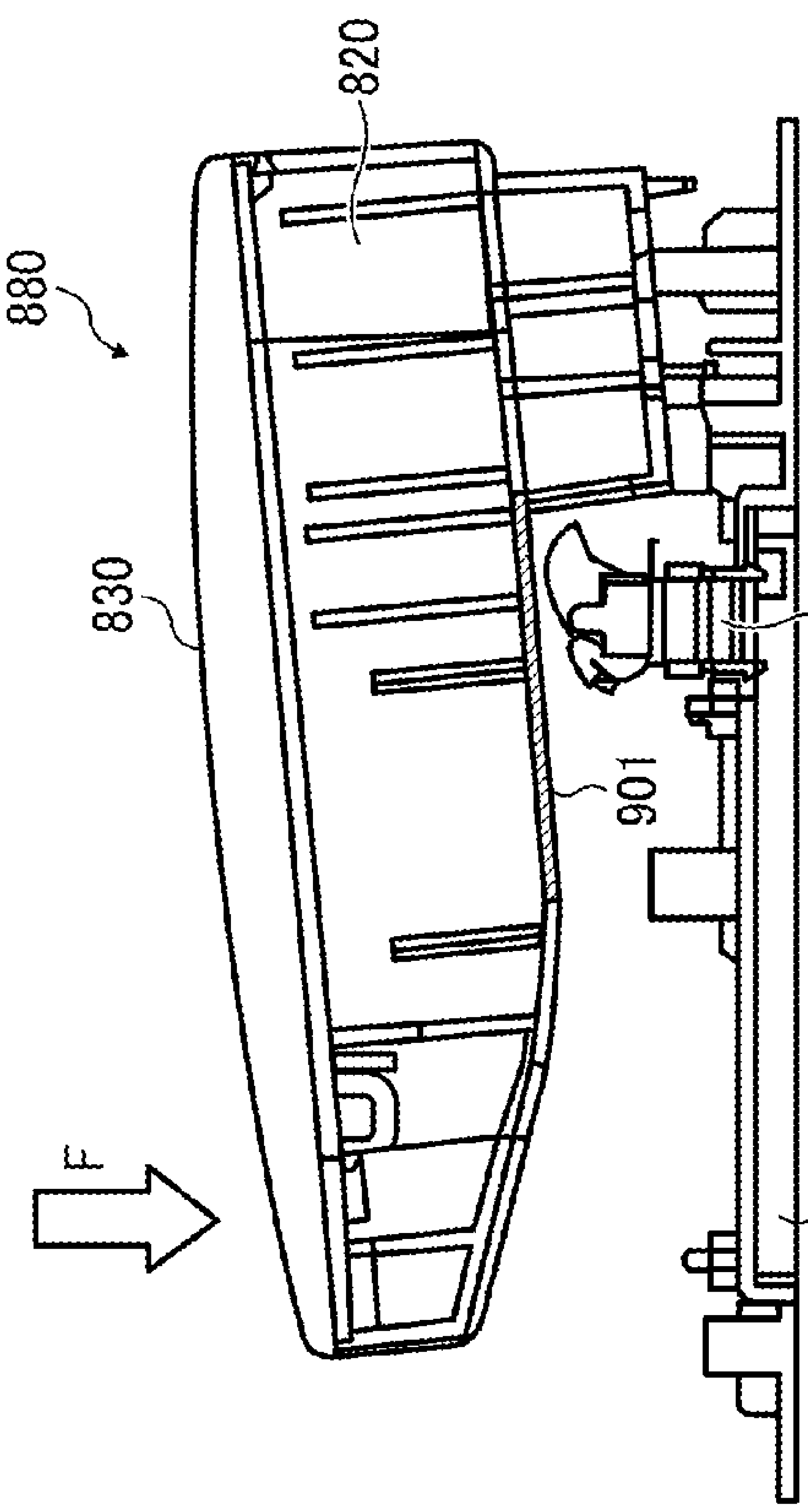


FIG. 25B

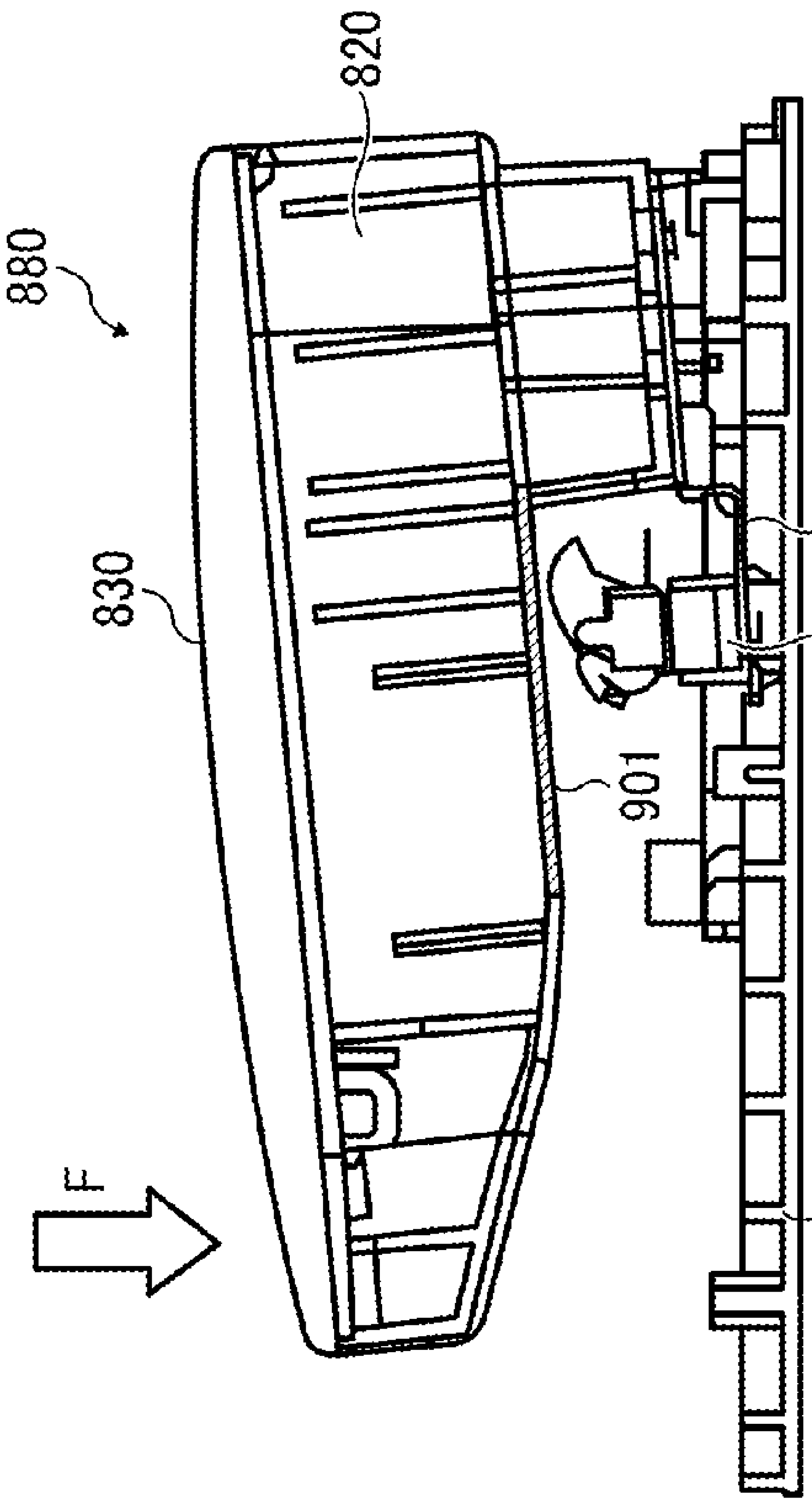
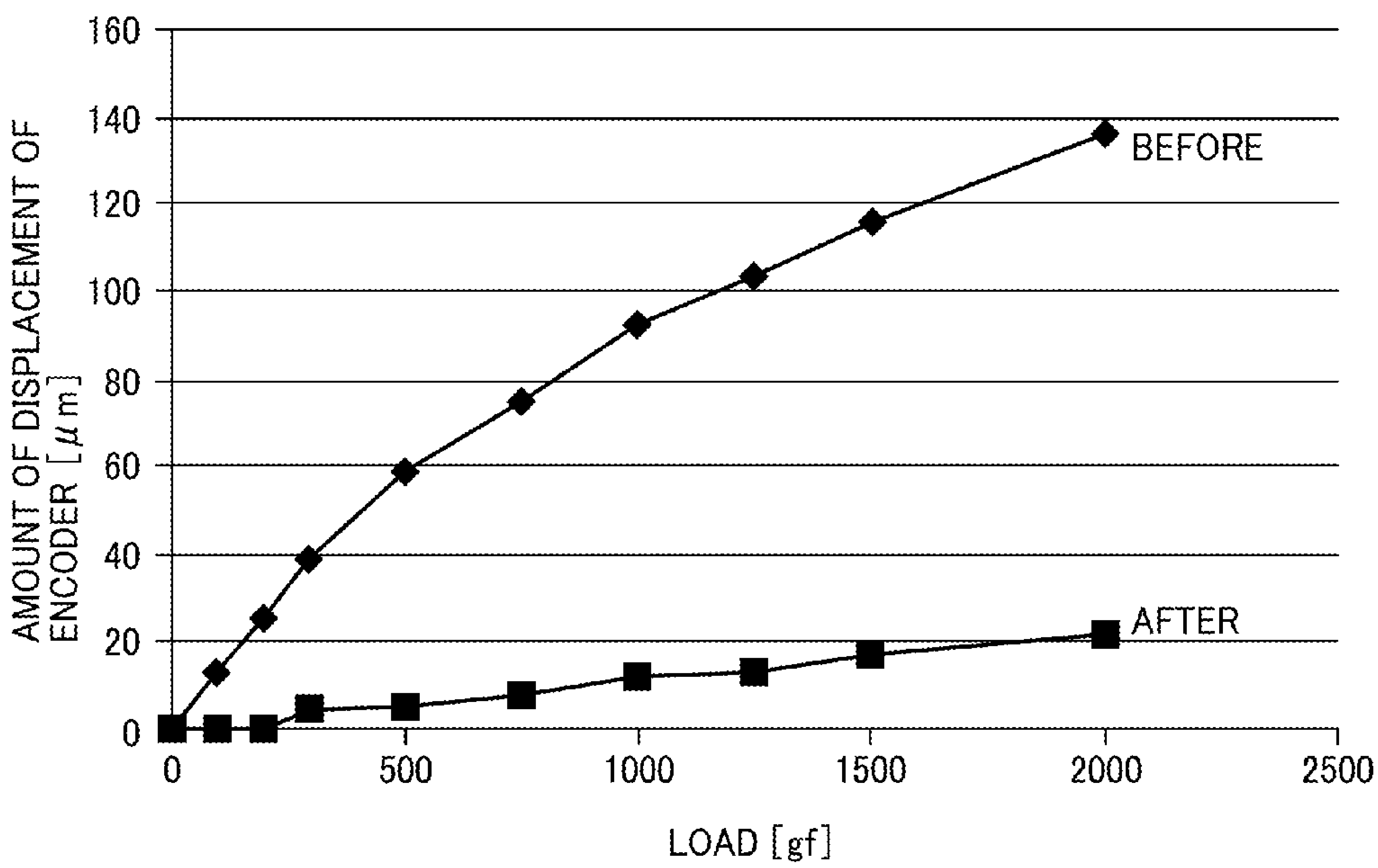


FIG. 26


160
140
120
100
80
60
40
20
0
AMOUNT OF DISPLACEMENT OF ENCODER [μm]
BEFORE
AFTER
0
500
1000
1500
2000
2500
LOAD [gf]

SHEET DISCRIMINATOR AND IMAGE FORMING APPARATUS INCORPORATING THE SHEET DISCRIMINATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is based on and claims priority pursuant to 35 U.S.C. §119(a) to Japanese Patent Application Nos. 2014-080785, filed on Apr. 10, 2014, and 2014-136498, filed on Jul. 2, 2014, in the Japan Patent Office, the entire disclosure of each of which is hereby incorporated by reference herein.

BACKGROUND

Technical Field

This disclosure relates to a sheet discriminator to discriminate sheet types, and an image forming apparatus including the sheet discriminator.

Related Art

In known image forming processes, to achieve higher printing quality, an image forming apparatus automatically discriminates sheet types and sets image forming conditions according to the detected sheet type.

An example of an image forming apparatus shows a configuration in which a sheet discriminator is disposed inside the image forming apparatus to discriminate information of a sheet being conveyed in a sheet conveying path.

This sheet discriminator includes an optical sensor that has a light emitting element and a light receiving element therein to function as a sheet information detector to detect information of a sheet. The light emitting element of the sheet information detector emits light to a surface of a sheet. Among the light emitted by the light emitting element, the light reflected on the surface of the sheet is received by a reflection light receiving element that is disposed at a position that can receive the reflected light and the light transmitted through the surface of the sheet is received by a transmission light receiving element that is received at a position that can receive the transmitted light.

Specifically, the sheet information detector causes the light emitting element to emit light to a sheet that is conveyed via a sheet conveying path and causes the reflection light receiving element to receive the light reflected on the sheet and the transmission light receiving element to receive the light transmitted through the sheet, so that the sheet information detector can detect sheet information based on optical information including a light amount of the received light.

Accordingly, based on the sheet information thus detected by the sheet information detector, a controller that functions as a sheet distinguisher to distinguish the sheet types, the image forming apparatus sets the image forming conditions according to the sheet type.

The sheet information detected by the sheet information detector includes glossiness of the sheet based on the reflected light received by the reflection light receiving element, thickness of the sheet based on the transmitted light received by the transmission light receiving element, and so forth. Based on the sheet information detected as described above, a controller that is a sheet distinguisher distinguishes a type of the sheet so as to set image forming conditions according to the respective types of the sheets.

SUMMARY

At least one aspect of this disclosure provides a sheet discriminator including an optical information detector, a sheet distinguisher, and a sheet thickness detector. The optical information detector includes a light emitter to emit light to a surface of a recording medium and a light receiver to receive the light emitted by the light emitter and detects information of the recording medium. The sheet distinguisher distinguishes a type of the recording medium based on the information detected by the optical information detector. The sheet thickness detector includes a displacement gauge and a displacement detector. The displacement gauge sandwiches the recording medium with an opposing member disposed facing the displacement gauge and moves from an initial position at which the displacement gauge stays when no recording medium is sandwiched with the opposing member. The displacement detector detects an amount of displacement of the displacement gauge. The sheet thickness detector detects a thickness of the recording medium based on detection results obtained by the displacement detector.

Further, at least one aspect of this disclosure provides an image forming apparatus including an apparatus body, the above-identified sheet discriminator disposed outside the apparatus body, and an image forming part to form an image on the recording medium.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a diagram illustrating a sheet discriminator according to an example of this disclosure;

FIG. **2**A is a cross sectional view illustrating the sheet discriminator when a sheet is inserted thereto through an opening;

FIG. **2**B is a cross sectional view illustrating the sheet discriminator when the sheet is pulled out from the opening of the sheet discriminator;

FIG. **3** is a diagram illustrating a configuration of an optical sensor and a processing device;

FIG. **4** is a diagram illustrating a structure of a vertical cavity surface emitting laser array (a VCSEL array);

FIG. **5** is a diagram illustrating an incident angle of an irradiation light to the sheet;

FIG. **6** is a diagram illustrating respective positions of receivers;

FIG. **7**A is a diagram illustrating a surface specular reflection light;

FIG. **7**B is a diagram illustrating a surface diffused reflection light;

FIG. **7**C is a diagram illustrating an internal reflection light;

FIG. **8** is a diagram illustrating the light received by receivers;

FIG. **9** is a diagram illustrating an incident light to a diffusion filter;

FIG. **10** is a diagram illustrating respective positions of different receivers;

FIG. **11** is a cross sectional view illustrating a configuration of a sheet discriminator, sectioned along a line corresponding to a length of a slit formed on a sheet loading table;

FIG. **12** is a perspective view illustrating a lower part of the sheet discriminator with an upper part of a feeler exposed from the slit formed on the sheet loading table;

FIG. **13**A is a diagram illustrating a state immediately before a sheet passes a contact position of an upper end of the feeler and a bottom face of a sheet information detecting sensor;

FIG. **13**B is a diagram illustrating a state in which the sheet is passing the contact part of FIG. **13**A;

FIG. **14** is a flowchart illustrating an example of control of sheet discrimination performed by the sheet discriminator of FIG. **1**;

FIG. **15**A is a cross sectional view illustrating the sheet discriminator when the sheet is inserted thereto through the opening;

FIG. **15**B is a cross sectional view illustrating the sheet discriminator when the sheet is pulled out from the opening of the sheet discriminator;

FIG. **16** is a diagram illustrating a configuration of an image forming system according to an example of this disclosure;

FIG. **17** is a diagram illustrating a configuration of an image forming apparatus included in the image forming system of FIG. **16**;

FIG. **18** is a diagram illustrating a configuration of a sheet finisher included in the image forming system of FIG. **16**;

FIG. **19** is a diagram illustrating another configuration of a sheet discriminator included in the image forming system of FIG. **16**;

FIG. **20**A is a cross sectional view illustrating the sheet discriminator when the sheet is inserted thereto through the opening;

FIG. **20**B is a cross sectional view illustrating the sheet discriminator when the sheet is pulled out from the opening of the sheet discriminator;

FIG. **21** is a flowchart illustrating an example of control of sheet discrimination performed by the sheet discriminator of FIG. **19**;

FIG. **22** is an exploded view illustrating a sheet discriminator according to an example of this disclosure;

FIG. **23** is a cross sectional view illustrating the sheet discriminator of FIG. **22**;

FIG. **24**A is a diagram illustrating an encoder feeler of a sheet thickness sensor of the sheet discriminator before the sheet is inserted;

FIG. **24**B is a diagram illustrating the encoder feeler after the sheet is inserted;

FIG. **25**A is a diagram illustrating a positional relation of a measuring reference face and the sheet thickness sensor attached directly to a base when a sheet information detector module of the sheet discriminator is warped;

FIG. **25**B is a diagram illustrating a positional relation of the measuring reference face and the sheet thickness sensor attached to the base via a bracket when the sheet information detector module of the sheet discriminator is warped; and

FIG. **26** is a graph showing results of tests regarding effectiveness to prevent misdetection in measurement of sheet thickness when the sheet information detector module of the sheet discriminator is warped intentionally.

DETAILED DESCRIPTION

It will be understood that if an element or layer is referred to as being "on", "against", "connected to" or "coupled to" another element or layer, then it can be directly on, against, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, if an element is referred to as being "directly on", "directly connected to" or "directly coupled to" another element or layer, then there are no intervening elements or layers present. Like numbers referred to like elements throughout. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Spatially relative terms, such as "beneath", "below", "lower", "above", "upper" and the like may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements describes as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, term such as "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors herein interpreted accordingly.

Although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, it should be understood that these elements, components, regions, layer and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present disclosure.

The terminology used herein is for describing particular embodiments and examples and is not intended to be limiting of exemplary embodiments of this disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "includes" and/or "including", when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Descriptions are given, with reference to the accompanying drawings, of examples, exemplary embodiments, modification of exemplary embodiments, etc., of an image forming apparatus according to exemplary embodiments of this disclosure. Elements having the same functions and shapes are denoted by the same reference numerals throughout the specification and redundant descriptions are omitted. Elements that do not demand descriptions may be omitted from the drawings as a matter of convenience. Reference numerals of elements extracted from the patent publications are in parentheses so as to be distinguished from those of exemplary embodiments of this disclosure.

This disclosure is applicable to any image forming apparatus, and is implemented in the most effective manner in an electrophotographic image forming apparatus.

In describing preferred embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this disclosure is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes any and all technical equivalents that have the same function, operate in a similar manner, and achieve a similar result.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, preferred embodiments of this disclosure are described.

Now, a description is given of a sheet discriminator **100** according to this disclosure with reference to FIGS. **1** through **26**.

First, a description is given of a configuration of the sheet discriminator **100** according to an example of this disclosure with reference to FIGS. **1** through **15**.

FIG. **1** is a diagram illustrating a configuration of the sheet discriminator **100**.

The sheet discriminator **100** includes an external case **101**. The external case **101** includes a sheet information detecting sensor **110**, a sheet thickness detecting sensor **170**, and a sheet loading table **120** therein. The sheet information detecting sensor **110** functions as an optical information detector to optically detect information to be used to discriminate the sheet P. The sheet thickness detecting sensor **170** functions as a sheet thickness detector to detect a thickness of the sheet P. The sheet loading table **120** functions as a sheet loading table on which the sheet P is located.

It is to be noted that the sheet information detecting sensor **110** and the sheet thickness detecting sensor **170** form an information detector **180** to detect information of the sheet P in the sheet discriminator **100**.

It is to be noted that the sheet information detecting sensor **110** and the sheet thickness detecting sensor **170** are connected via a controller **600** that functions as a sheet distinguisher (see FIG. **3**). Based on whether the thickness of the sheet is detected by the sheet thickness detecting sensor **170** or not, the controller **600** controls start and stop of light emission of a light source **111** (see FIG. **3**) of the sheet information detecting sensor **110** via a light emission processing unit **130** that functions as a light emission controller.

The external case **101** has sidewalls. An opening **102** is formed on one of the sidewalls of the external case **101**. The sheet P is inserted into and removed from the opening **102** so that the sheet P is loaded on the sheet loading table **120**. The sheet P is inserted into the opening **102** of the sheet discriminator **100** in a direction indicated by arrow B in FIG. **1** and pushed further until the sheet P contacts an end face **103** of the opening **102** or approaches the end face **103**.

At this time, it is preferable that the operator grabs both left and right ends of the sheet P with respect to the direction B and inserts the sheet while checking that the sheet P has no deformation such as wrinkle or crease on the sheet P. It is to be noted that sheet insertion to the opening **102** is not limited to the above-described way but is applicable with any way of sheet insertion even if the sheet P can be inserted into the opening **102** of the sheet discriminator **100** horizontally.

To discriminate a type of the sheet P, the operator inserts the sheet P into the external case **101** via the opening **102** while checking that there is no deformation such as curls on the sheet P held by the operator. Then, the operator loads the sheet P on the sheet loading table **120**, so that the sheet information detecting sensor **110** detects information of the sheet P while the sheet P is loaded on the sheet loading table **120**.

By so doing, the sheet information detecting sensor **110** does not detect deformed portions on the sheet P and detects correct sheet information, and therefore performance of accurate discrimination of sheet types is prevented from being degraded.

FIGS. **2**A and **2**B are cross sectional views of the sheet discriminator **100**, viewed from a direction indicated by arrow A in FIG. **1**. Specifically, FIG. **2**A is a cross sectional view illustrating the sheet discriminator **100** when the sheet P is inserted thereto through the opening **102** of the sheet discriminator **100** and FIG. **2**B is a cross sectional view illustrating the sheet discriminator **100** when the sheet P is pulled out from the opening **102** of the sheet discriminator **100**.

It is to be noted that respective sensors such as the sheet information detecting sensor **110** and the sheet thickness detecting sensor **170** are drawn in a simplified way in FIGS. **2**A and **2**B.

The sheet information detecting sensor **110** is disposed at an upper part of an inside of the external case **101** of the sheet discriminator **100**.

The sheet loading table **120** and the sheet thickness detecting sensor **170** are disposed at a lower art of the inside of the external case **101** of the sheet discriminator **100**.

The sheet loading table **120** is disposed facing the sheet information detecting sensor **110** across a gap therebetween. The sheet thickness detecting sensor **170** is disposed upstream from a sheet information detectable position of the sheet information detecting sensor **110**.

With this configuration, when the sheet P is inserted through the opening **102** to the sheet information detectable position so that the sheet information detecting sensor **110** can detect sheet information, the sheet thickness detecting sensor **170** can detect the thickness of the sheet P reliably. Accordingly, the sheet thickness detecting sensor **170** can detect the thickness of the sheet P more accurately, and accuracy in sheet discrimination can be more enhanced.

It is to be noted that, even though the sheet thickness detecting sensor **170** is disposed at the above-described position, the position to set the sheet thickness detecting sensor **170** is not limited thereto. For example, the sheet thickness detecting sensor **170** can be disposed in an upper part inside the external case **101** of the sheet discriminator **100** and aligned with the sheet information detecting sensor **110**. The sheet thickness detecting sensor **170** can be disposed at any position where the sheet thickness detecting sensor **170** can detect the thickness of the sheet P that is inserted into the sheet discriminator **100** through the opening **102**.

Further, biasing members **150** such as spring are disposed facing the sheet information detecting sensor **110** with the sheet loading table **120** interposed therebetween. The sheet loading table **120** is biased by the biasing members **150** in a direction indicated by arrows BF in FIGS. **2**A and **2**B, that is, toward the sheet information detecting sensor **110**.

As illustrated in FIG. **3**, the sheet information detecting sensor **110** includes a light source **111**, a collimator lens **112**, receivers **113**, **114**, **115**, **118**, and **160**, polarizing filters **116** and **117**, and dark boxes (camera obscuras) **119**A and **119**B to accommodate these optical units therein.

Each of the dark boxes **119**A and **119**B is a metal box such as an aluminum box, and anodic oxide coating with black dye on a surface thereof in order to reduce the impact of ambient light and stray light.

The light source **111** functions as a light emitter and includes multiple light emitting elements **111***a*, which are vertical cavity surface emitting laser (VCSEL). Specifically, the light source **111** includes a VCSEL array **111**LA. As illustrated in FIG. **4**, the light source **111** of the sheet information detecting sensor **110** includes a two dimensional array with nine (9) light emitting elements **111***a*. The VCSEL array **111**LA includes electrode pads **111***b* and wiring members **111***c*. Each wiring member **111***c* connects one of the multiple light emitting elements **111***a* with a corresponding one of the electrode pads **111***b*.

The light source **111** is disposed such that linearly polarized light of S-polarized light to the sheet P is emitted. As illustrated in FIG. **5**, an incidence angle θ of light from the light source **111** to the sheet P is 80 degrees. The light emission processing unit **130** turns on/off the light source **111**.

The collimator lens **112** is disposed on a light path of light emitted from the light source **111** to make the light substantially parallel, which is hereinafter referred to as a substantially parallel light. The substantially parallel light passes through the collimator lens **112** then through an opening provided on the dark box **119**A, and emits the light to the sheet P. It is to be noted that a center of a light emission region on a surface of the sheet P is hereinafter referred to as a "center of light emission (LC)" and the light passed through the collimator lens **112** is also referred to as an "irradiation light".

When the light enters onto a border surface of a medium, a surface that contains an incident light (an incoming radiation) and a normal line of a border surface standing at a light incident point. When the incident light includes multiple light beams, each light beam has the plane of incidence. Here, for convenience, the plane of incidence of light incoming to the center of light emission is referred to as a "plane of incidence" of the sheet P. Specifically, the plane of incidence of a sheet contains the center of light emission (LC) and is parallel to X and Z surfaces of the sheet P.

It is to be noted that terms "S-polarized light" and "P-polarized light" are used for not only the incident light to the sheet P but also a reflection light on the sheet P based on a polarization direction of the incident light to the sheet P for easy understanding of this technique. On the plane of incidence, a polarization direction identical to the incident light is referred to as "S-polarized light" and a polarization direction perpendicular to the incident light is referred to as "P-polarized light". In this example, the incident light is an S-polarized light.

The polarizing filter **116** is disposed on a +Z side of the center of light emission. The polarizing filter **116** is a polarizing filter that transmits the P-polarized light and blocks or reflects the S-polarized light. It is to be noted that a polarizing beam splitter that has the same functions as the polarizing filter **116** can be employed instead of the polarizing filter **116**.

The receiver **114** is disposed on the +Z side of the polarizing filter **116** and functions as a light receiver to receive the light transmitted through the polarizing filter **116**. As illustrated in FIG. **6**, a line L**1** connects the center of light emission, a center of the polarizing filter **116**, and a center of the receiver **114**. The line L**1** and the surface of the sheet P form an angle $\psi 1$ of 90 degrees.

The receiver **113** is disposed on the +X side of the center of light emission with respect to an X axis. As illustrated in FIG. **6**, a line L**2** connects the center of light emission and a center of the receiver **113**. The line L**2** and the surface of the sheet P form an angle $\psi 2$ of 170 degrees.

A center of the light source **111**, the center of light emission, the center of the polarizing filter **116**, and respective centers of the receivers **113**, **114**, **115**, and **118** fall on the substantially identical vertical plane.

The reflection light reflected on the sheet P when the sheet P is irradiated can be separated to reflection light reflected on the surface of the sheet P and reflection light reflected from an inside of the sheet P. Further, the reflection light reflected on the surface of the sheet P can be separated to specular reflection light (SRL) and diffused reflection light (DRL).

For convenience, the specular reflection light reflected on the surface of the sheet P is hereinafter referred to as a "surface specular reflection light (SRL)" (see FIG. **7**A) and the diffused reflection light reflected on the surface of the sheet P is hereinafter referred to as a "surface diffused reflection light (DRL)" (see FIG. **7**B).

The surface of the sheet P includes plane portions and sloped portions. Based on a rate of the plane portions and the sloped portions, smoothness of the surface of the sheet P is determined. The light reflected on the plane portions becomes the surface specular reflection light and the light reflected on the sloped portions becomes the surface diffused reflection light. The surface diffused reflection light is the light fully reflected from an object (i.e., the sheet P) and a reflection direction has isotropy. As smoothness increases, the level of the surface specular reflection light rises.

By contrast, when the sheet P is a regular printing sheet, the reflection light reflected from the inside of the sheet P scatters in the fibers of the sheet P. Therefore, the reflection light is the diffused reflection light because the light scatters multiply in the sheet P. Hereinafter, for convenience, the reflection light reflected from the inside of the sheet P is also referred to as an "internal reflection light (IRL)" (see FIG. **7**C). Similar to the surface diffused reflection light, the internal reflection light is the light fully reflected from an object (i.e., the sheet P) and the reflection direction is isotropic.

The polarization directions of the surface specular reflection light and the surface diffused reflection light toward the receiver (i.e., the receiver **114**) are the same as the polarization direction of the incident light.

In order to rotate the polarization direction on the surface of the sheet S, the incident light is reflected on the sloped surface that is slanted to the rotation of the polarization direction with respect to an incident direction. Here, since the center of the light source (i.e., the light source **111**), the center of light emission, and the center of each receiver (i.e., the receivers **113** and **114**) fall on the same plane, the reflection light in the polarization direction rotated on the surface of the sheet P is not reflected in any direction of the receiver.

By contrast, the polarization direction of the internal reflection light is rotated with respect to the polarization direction of the incident light. It is thought that the light entered into the inside of the sheet (i.e., the sheet P) passes through the fibers of the sheet and optically rotates during multiple scattering in the sheet, thereby rotates the polarization direction.

The reflection light including the surface diffused reflection light and the internal reflection light enters into the polarizing filter **116**, as illustrated in FIG. **8**.

Since the surface diffused reflection light is the S-polarized light that is the same as the incident light. Therefore, the polarizing filter **116** blocks or reflects the surface diffused reflection light. By contrast, the internal reflection light includes both the S-polarized light and the P-polarized light. Therefore, a component of the P-polarized light passes through the polarizing filter **116**. Specifically, the component of the P-polarized light contained in the internal reflection light is received by the receiver **114** (see FIG. **9**).

It is to be noted that the component of the P-polarized light included in the internal reflection light is also referred to as a "P-polarized light internal reflection light", for convenience. In addition, a component of the S-polarized light included in the internal reflection light is also referred to as an "S-polarized light internal reflection light".

The level of the P-polarized light internal reflection light is proved to have a correlation to thickness and density of the sheet P. It is because the level of the P-polarized light internal reflection light depends on a path length when the sheet P passes through the fibers in the sheet.

The receiver **113** receives reflection light having the surface specular reflection light, the surface diffused reflection light, and the internal reflection light. At this light receiving position, the level of the surface diffused reflection light and the level of the internal reflection light are significantly smaller than the level of the surface specular reflection light. Therefore, it is regarded as that the level of light received by the receiver **113** substantially corresponds to the level of the surface specular reflection light (see FIG. **8**).

The receiver **115** that functions as a light receiver is disposed at a position to receive the surface diffused reflection light and the internal reflection light. For example, as illustrated in FIG. **10**, a line L**3** connects the center of light emission and a center of the receiver **115**. The line L3 and the surface of the sheet P form an angle ψ3 of 120 degrees. The center of the light source **111**, the center of light emission, the center of the polarizing filter **116**, and the respective centers of the receivers **113**, **114**, **115**, and **118** fall on the substantially same vertical plane.

The polarizing filter **117** is disposed on the light path of the surface diffused reflection light and the internal reflection light. The polarizing filter **117** is a polarizing filter that transmits the P-polarized light and blocks or reflects the S-polarized light.

The receiver **118** is disposed on a light path of the light transmitted through the polarizing filter **117**. The receiver **118** receives a component of the P-polarized light included in the internal reflection light.

For example, as illustrated in FIG. **10**, a line L**4** connects the center of light emission, a center of the polarizing filter **117**, and a center of the receiver **118**. The line L4 and the surface of the sheet P form an angle ψ4 of 150 degrees. The center of the light source **111**, the center of light emission, the center of the polarizing filter **116**, the center of the polarizing filter **117**, and the respective centers of the receivers **113**, **114**, **115**, and **118** fall on the substantially same vertical plane.

The receiver **160** illustrated in FIG. **3** functions as a transmitted light receiver and is disposed at a position to receive a light beam that is transmitted through the sheet P out of the light beams emitted from the light source **111** and irradiated to the sheet P.

The receivers **113**, **114**, **115**, **118**, and **160** output respective electrical signals (current signals) corresponding to respective received light levels to the light emission processing unit **130**.

As illustrated in FIG. **3**, the light emission processing unit **130** includes a light source driver **131**, a current-to-voltage converter **132**, and an analog-to-digital (AD) converter **133**. The light emission processing unit **130** is connected to the dark box **119**A.

The light source driver **131** outputs the light source driving signal to the light source **111** according to instructions issued by the controller **600**.

The current-to-voltage converter **132** converts current signals inputted by each receiver to voltage signals.

The AD converter **133** converts analog signals passing through the current-to-voltage converter **132** to digital signals and outputs the converted digital signals to the controller **600**.

As described in this example, by including information obtained by the receiver **160** that receives a transmitted light in addition to information obtained by the receivers **113**, **114**, **115**, and **118** receiving the reflection light, the sheet discriminator **100** can discriminate the type of the sheet P more precisely.

A thickness of the sheet P can be obtained as information of the sheet P based on the levels of transmitted light received by the receiver **160**. When the sheet P is not inserted into the sheet discriminator **100** through the opening **102** and is not located between the light source **111** and the receiver **160**, the receiver **160** receives a constant amount of light emitted from the light source **111**.

When the sheet P is inserted into the opening **102** and located between the light source **111** and the receiver **160**, the level of light received by the receiver **160** varies according to the thickness of the sheet P. Based on the light level, the controller **600** can obtain the thickness of the sheet P with transform expressions and conversion tables, both of which are previously prepared to convert the light level to an amount of thickness of the sheet P.

By contrast, as described above, the sheet discriminator **100** according to this example includes the sheet thickness detecting sensor **170** to detect the thickness of the sheet P that is inserted into the opening **102** is provided, separately from the sheet information detecting sensor **110**.

FIG. **11** is a cross sectional view illustrating a configuration of the sheet discriminator **100**, sectioned along a line corresponding to a length of a slit **120***a* formed on the sheet loading table **120**.

It is to be noted that the biasing members **150** to bias the sheet loading table **120** as illustrated in FIGS. **2**A and **2**B are omitted in FIG. **11**.

The sheet thickness detecting sensor **170** is an encoder that functions as a displacement detector to detect an amount of displacement according to the thickness of the sheet P. As illustrated in FIG. **11**, the sheet thickness detecting sensor **170** includes a feeler **171** and a transmission type optical sensor **172**.

The feeler **171** that functions as a displacement gauge has multiple slits **171***b* formed at constant angled pitches.

The transmission type optical sensor **172** that functions as a displacement detector detects the multiple slits **171***b* of the feeler **171**.

FIG. **12** is a perspective view illustrating a lower part of the sheet discriminator **100**.

As illustrated in FIG. **12**, an upper part of the feeler **171** of the sheet thickness detecting sensor **170** is exposed from the slit **120***a* formed on the sheet loading table **120** so that the upper part of the feeler **171** is located on a path of insertion of the sheet P in the gap formed between the sheet loading table **120** and the sheet information detecting sensor **110**.

When the sheet P is not inserted in the opening **102**, the feeler **171** is located at an initial position at which an upper end **171***a* of the feeler **171** is in contact with a bottom face **110***a* of the sheet information detecting sensor **110**, which functions as an opposing member. When the feeler **171** is at the initial position, the sheet P is not sandwiched by the feeler **171** and the sheet information detecting sensor **110**, and therefore the sheet thickness detecting sensor **170** detects the thickness of the sheet P as "0".

FIG. **13**A is a diagram illustrating a state immediately before the sheet P passes a contact position of the upper end **171***a* of the feeler **171** and the bottom face **110***a* of the sheet information detecting sensor **110**. FIG. **13**B is a diagram illustrating a state in which the sheet P is passing the contact part of FIG. **13**A.

As illustrated in FIG. **13**A, when the sheet P is inserted into the opening **102** to pass the contact position where the upper end **171***a* of the feeler **171** and the bottom face **110***a* of the sheet information detecting sensor **110**, the sheet P presses the feeler **171**. Consequently, as illustrated in FIG. **13**B, the feeler **171** rotates about a rotary shaft **173** thereof in a clockwise direction in FIG. **13**B. Accordingly, the sheet P is sandwiched between the feeler **171** and the sheet information detecting sensor **110**.

At this time, the optical sensor **172** detects the multiple slits **171***b* passing a position facing a sensor part **172***a* thereof, and a rotation amount of the feeler **171** is obtained based on detection results of the optical sensor **172**. The thus obtained rotation amount of the feeler **171** is then converted to an amount of thickness of the sheet P by a given expression or equation. Accordingly, the thickness of the sheet P can be obtained.

It is to be noted that the configuration of the sheet thickness detecting sensor **170** is not limited to the above-described configuration. For example, any configuration including a displacement sensor that can detect the thickness of the sheet P can be applied to this disclosure.

The thickness of the sheet P can be obtained using the sheet information detecting sensor **110**. Specifically, the light emitted by the light source **111** and transmitted through the sheet P is received by the receiver **160**. Based on the results obtained by this operation, the thickness of the sheet P can be detected. However, as the sheet P becomes thicker, the receiver **160** receives a lower level of transmitted light.

For this reason, depending on the sensitivity of the receiver **160**, it is likely that the level of the transmitted light received by the receiver **160** is too low to detect the thickness of the sheet P properly. Therefore, when a thick paper is employed as the sheet P, the thickness of the sheet P cannot be detected accurately and, as a result, accuracy of sheet discrimination is likely to be degraded.

By contrast, by employing the sheet thickness detecting sensor **170** to detect the thickness of the sheet P as described above, the thickness of the sheet P can be detected more accurately compared to the case in which the thickness of the sheet P is obtained based on detection results of the transmitted light received by the receiver **160**.

Specifically, the sheet thickness detecting sensor **170** detects the thickness of the sheet P based on an amount of displacement of the feeler **171** whose position is physically changed from the initial position according to the thickness of the sheet P. Accordingly, even though the sheet P has a thickness difficult for the sheet information detecting sensor **110** to precisely detect optically, the sheet thickness detecting sensor **170** that functions as a sheet thickness detector can detect the thickness of the sheet P accurately.

Therefore, by including the detection results obtained by the sheet thickness detecting sensor **170** to sheet information used to distinguish the sheet P by the controller **600**, the sheet P can be discriminate using information regarding the sheet P having the thickness detected precisely. As a result, the sheet discriminator **100** can prevent degradation of accuracy of sheet discrimination due to inaccurate detection of the thickness of the sheet P when a thick paper is used as the sheet P.

It is to be noted that, when the sheet P is a thin paper, the level of transmitted light through the sheet P is high. Therefore, the thickness of the sheet P can be detected relatively precisely based on the level of transmitted light received by the receiver **160**.

Therefore, for example, when the thickness of the sheet P detected by the sheet thickness detecting sensor **170** is lower (thinner) than a given thickness previously set, the level of light received by the receiver **160** is additionally used as sheet information to obtain the thickness of the sheet P. By so doing, the sheet thickness detecting sensor **170** can detect the thickness of the sheet P more accurately when the sheet P is a thin paper, and accuracy in sheet discrimination can be more enhanced.

Next, a description is given of control of sheet discrimination performed by the sheet discriminator **100** with reference to FIGS. **2**A, **2**B, and **14**.

FIG. **14** is a flowchart illustrating an example of control of sheet discrimination performed by the sheet discriminator **100** according to this example.

As illustrated in FIG. **2**A, the sheet P is inserted toward the end face **103** of the opening **102** of the sheet discriminator **100** in a direction indicated by arrow C, as described in step S**1** in FIG. **14**. When the sheet thickness detecting sensor **170** detects the thickness of the sheet P, which is YES in step S**2** in FIG. **14**, the sheet information detecting sensor **110** starts light emission, as described in step S**3** in FIG. **14**. When the sheet thickness detecting sensor **170** does not detect the thickness of the sheet P, which is NO in step S**2** in FIG. **14**, the procedure is repeated until the sheet thickness detecting sensor **170** detects thickness of the sheet P.

The sheet information detecting sensor **110** performs at least one information detection D**1** in FIG. **2**A with respect to the sheet P that is further inserted toward the end face **103**. After the sheet P has reached the end face **103** of the opening **102**, the sheet P is removed. When pulling out the sheet P from the opening **102**, the sheet P moves in a direction indicated by arrow D in FIG. **2**B. Hereinafter, the at least one information detection D**1** is occasionally referred to as a first information detection(s) D**1**.

At this time, the sheet information detecting sensor **110** performs at least another one information detection D**2** in FIG. **2**B. Hereinafter, the at least another one information detection D**2** is occasionally referred to as a second information detection(s) D**2**. Accordingly, the sheet information detecting sensor **110** detects the sheet P at different points on the sheet P in the first information detection(s) D**1** and the second information detection(s) D**2**.

As described above, the sheet discriminator **100** according to this example slides the sheet P in the opening **102** for multiple detections. Based on the information obtained by the sheet information detecting sensor **110**, the controller **600** discriminates the sheet P, as described in step S**4** in FIG. **14**.

After the sheet P is removed from the opening **102** and is no longer detected by the sheet thickness detecting sensor **170**, which is YES in step S**5** in FIG. **14**, the controller **600** causes the sheet information detecting sensor **110** to stop light emission, as described in step S**6** in FIG. **14**. Alternatively, after the sheet information detecting sensor **110** completes a given number of information detections, which is YES in step S**5** in FIG. **14**, the controller **600** causes the sheet information detecting sensor **110** to stop light emission, as described in step S**6** in FIG. **14**. When the sheet P is detected by the sheet thickness detecting sensor **170** and the sheet information detecting sensor **110** does not complete the given number of information detections, which is NO in step S**5** in FIG. **14**, the procedure is repeated until the condition of step S**5** is satisfied.

As described above, the controller **600** discriminates the sheet P based on the sheet information obtained from the multiple points on the sheet P. This operation encourages averaging discrimination results and obtaining the median value of the discrimination results, and therefore measurement errors such as noise can be reduced or prevented and more precise sheet discrimination of the sheet P can be performed.

Further, the sheet discriminator **100** according to this example causes the sheet information detecting sensor **110** to emit light when the sheet thickness detecting sensor **170** detects the thickness of the sheet P. By so doing, when the sheet P is inserted into the opening **102** of the sheet discriminator **100**, the sheet information detecting sensor **110** can start light emission without any operator handling.

Further, when the sheet thickness detecting sensor **170** detects no thickness of the sheet P, the controller **600** causes the sheet information detecting sensor **110** to stop emitting light. By so doing, when the sheet P is pulled out from the opening **102** of the sheet discriminator **100**, the sheet information detecting sensor **110** can stop light emission without any operator handling.

Further, in the sheet discriminator **100** according to this example, the sheet thickness detecting sensor **170** is used not only for detecting the thickness of the sheet P but also for detecting presence or absence of the sheet P at a given position on the sheet loading table **120**.

Specifically, the sheet thickness detecting sensor **170** detects the thickness of the sheet P and, at the same time, detects the presence of the sheet P on the sheet loading table **120**.

On the contrary, when the sheet thickness detecting sensor **170** detects no thickness of the sheet P (i.e., when the feeler **171** is located at the initial position and the thickness of the sheet is indicated as "0"), the sheet thickness detecting sensor **170** detects that there is no sheet on the sheet loading table **120**.

Depending on whether or not the sheet thickness detecting sensor **170** detects the thickness of the sheet P, the controller **600** regulates timing to cause the light source **111** of the sheet information detecting sensor **110** to start or stop light emission.

By so doing, the light emission by the light source **111** is performed based on the timing. With this operation, the sheet information detecting sensor **110** performs light emission when the sheet information detecting sensor **110** detect information of the sheet P. Accordingly, when compared with a case in which the sheet information detecting sensor **110** constantly emits light, the sheet discriminator **100** according to this example can extend the life span of the sheet information detecting sensor **110** and reduce waste energy consumption thereof.

A sheet detecting sensor can be provided to the sheet discriminator **100** to detect whether the sheet P is present or absent at the given position so as to regulate the timing to cause the light source **111** to start or stop light emission based on the detection results obtained by the sheet detecting sensor. However, compared with the configuration including the sheet detecting sensor, the sheet discriminator **100** having the configuration without the sheet detecting sensor can reduce the cost related to the sheet detecting sensor.

Further, as illustrated in FIGS. **2**A and **2**B, the biasing members **150** press the sheet loading table **120** toward the sheet information detecting sensor **110**. By so doing, a detection face of the sheet information detecting sensor **110** can contact or approach the sheet P. As a result, while reducing or preventing disturbances such as deformation of the sheet P and entry of ambient light, the sheet discriminator **100** can discriminate the type of the sheet P more precisely.

Further, in FIGS. **2**A and **2**B, the sheet information detecting sensor **110** is disposed on the upper side of the sheet discriminator **100** and the sheet loading table **120** is disposed on the lower side with the sheet discriminator **100** arranged therebetween. Specifically, the sheet loading table **120** is disposed below the sheet information detecting sensor **110**. However, the positional relation of the sheet information detecting sensor **110** and the sheet loading table **120** is not limited thereto as long as a distance between the detection face of the sheet information detecting sensor **110** and the sheet P is secured and the detection face of the sheet information detecting sensor **110** can contact the sheet P.

However, the configuration in which the sheet information detecting sensor **110** is disposed above the sheet loading table **120** can avoid foreign materials brought into the sheet discriminator **100** via the sheet P and dust of the sheet P adhering and entering to the sheet information detecting sensor **110**. Therefore, it is preferable that the sheet information detecting sensor **110** and the sheet loading table **120** have the positional relation as illustrated in FIGS. **2**A and **2**B.

Further, this configuration does not have any restriction in handling sheet discrimination. For example, no pressure is applied between the sheet information detecting sensor **110** and the sheet P, the sheet P is not deformed during a detecting operation, and a user does not have to apply any force when handling the sheet P. Therefore, data of the surface of the sheet P can be obtained easily.

It is to be noted that, at least, the sheet information detecting sensor **110** has a function to obtain information on the surface of the sheet P.

A light-emitting diode (LED) is generally employed as the light source **111** of the sheet information detecting sensor **110**. By employing a surface emitting laser having VCSEL elements, surface information of the sheet P can be detected more precisely. Therefore, more precise detection results can be obtained.

Further, the sheet information detecting sensor **110** is preferably include at least a specular reflection light receiver (e.g., the receivers **113**, **114**, **115**, and **118**) to receive specular reflection light reflected on the sheet P and a diffused reflection light receiver (e.g., the receiver **113**) to receive diffused reflection light reflected on the sheet P out of the light beams emitted from the light source **111** and irradiated to the sheet P. The sheet information detecting sensor **110** can be a known optical sensor.

Since the sheet information detecting sensor **110** has multiple sensors disposed at different angles to detect scattered light beams of diffused reflection light, more precise detection results of information can be obtained than the information obtained from specular reflection light alone.

Now, a description is given of a sheet discriminator **100** according to another example of this disclosure, with reference to FIGS. **15**A and **15**B.

FIGS. **15**A and **15**B are cross sectional views of the sheet discriminator **100**, viewed from a direction indicated by arrow A in FIG. **1**. Specifically, FIG. **15**A is a cross sectional view illustrating the sheet discriminator **100** when the sheet P is inserted thereto through the opening **102** of the sheet discriminator **100** and FIG. **15**B is a cross sectional view illustrating the sheet discriminator **100** when the sheet P is pulled out from the opening **102** of the sheet discriminator **100**.

In the sheet discriminator **100** according to this example, the sheet thickness detecting sensor **170** is located downstream from the sheet information detecting sensor **110** in a sheet inserting direction indicated by arrow C illustrated in FIGS. **15**A and **15**B. Specifically, the positions of the sheet information detecting sensor **110** and the sheet thickness detecting sensor **170** in the sheet inserting direction are switched from those illustrated in FIGS. **2**A and **2**B, and therefore the sheet thickness detecting sensor **170** is disposed closer to the end face **103** than the sheet information detecting sensor **110** is.

It is to be noted that the configuration and the controller of light emission of the light source **111** of the sheet information detecting sensor **110** of the sheet discriminator **100** illustrated in FIGS. **15**A and **15**B are basically identical to the configuration and the control of the sheet discriminator **100** illustrated in FIGS. **2**A and **2**B, except for the above-described positional relation of the sheet information detecting sensor **110** and the sheet thickness detecting sensor **170**. Therefore, detailed descriptions of the other components and functions are omitted here.

By disposing the sheet thickness detecting sensor **170** downstream from the sheet information detecting sensor **110** in the sheet inserting direction to the opening **102**, this sheet discriminator **100** can achieve the following effects.

In the configuration of the sheet discriminator **100** according to this example, as illustrated in FIGS. **15**A, and **15**B, when the sheet P is detected by the sheet thickness detecting sensor **170**, the sheet P has reached a position facing a sheet information detectable position of the sheet information detecting sensor **110**. Therefore, when the sheet P is inserted into the opening **102**, the controller **600** causes the sheet information detecting sensor **110** to start light emission in a state in which the sheet P has reached the position facing the sheet information detecting sensor **110**.

Accordingly, the above-described configuration of the sheet discriminator **100** illustrated in FIGS. **15**A and **15**B can reduce a time period from the start of light emission of the sheet information detecting sensor **110** to the detection when compared with the configuration of the sheet discriminator **100** in which the sheet information detecting sensor **110** starts light emission and the sheet P reaches at the position facing the sheet information detecting sensor **110**. Since the time of light emission of the sheet information detecting sensor **110** can be reduced, the sheet discriminator **100** according to this example can extend the life span of the sheet information detecting sensor **110** and reduce waste energy consumption thereof.

Next, a description is given of a configuration of an image forming system **1** according to another example of this disclosure, with reference to FIG. **16**.

As illustrated in FIG. **16**, the image forming system **1** includes an image forming apparatus **2** and a sheet finishing apparatus **3** that functions as a sheet finisher.

Further, the sheet discriminator **100** is disposed in the image forming system **1** outside the image forming apparatus **2**. Details of the sheet discriminator **100** is described below.

The image forming apparatus **2** and the sheet finishing apparatus **3** are connected to communicate with each other. In the image forming system **1**, after the image forming apparatus **2** has formed an image on the sheet P, the sheet finishing apparatus **3** accepts the sheet P from the image forming apparatus **2** for various post-processing operations to the sheet P.

The post-processing operations include, for example, a corner binding process, a center folding process, and the like. The center folding process includes a center binding process. The sheet finishing apparatus **3** that executes the above-described various post-processing operations includes a sheet discharge mode, a corner binding mode, and a center binding mode.

FIG. **17** is a diagram illustrating a configuration of the image forming apparatus **2** included in the image forming system **1** of FIG. **16**.

The image forming apparatus **2** may be a copier, a printer, a scanner, a facsimile machine, a plotter, and a multifunction peripheral or a multifunction printer (MFP) having at least one of copying, printing, scanning, facsimile, and plotter functions, or the like. According to the present example, the image forming apparatus **2** is an electrophotographic printer that forms toner images on a sheet or sheets by electrophotography.

More specifically, the image forming apparatus **2** functions as a printer. However, the image forming apparatus **2** can expand its function as a copier by adding a scanner as an option disposed on top of an apparatus body of the image forming apparatus **2**. The image forming apparatus **2** can further obtain functions as a facsimile machine by adding an optional facsimile substrate in the apparatus body of the image forming apparatus **2**.

Further, this disclosure is also applicable to image forming apparatuses adapted to form images through other schemes, such as known ink jet schemes, known toner projection schemes, or the like as well as to image forming apparatuses adapted to form images through electro-photographic schemes.

The image forming apparatus **2** includes an apparatus body **400**, an image reading device **300**, and an automatic document feeder (ADF) **500**.

The apparatus body **400** encases an image forming part **420** and sheet trays **430***a* and **430***b* therein. The sheet trays **430***a* and **430***b* are vertically disposed below the image forming part **420**. The sheet trays **430***a* and **430***b* have sheet feed rollers **414***a* and **414***b*, respectively, and accommodate the sheet P that functions as a recording medium. After the sheet P being fed by a selected one of the sheet feed rollers **414***a* and **414***b*, the sheet P accommodated in each of the sheet trays **430***a* and **430***b* is conveyed upwardly along a corresponding sheet conveying path before reaching a registration roller pair **413**.

The image forming part **420** includes a photoconductor drum **401** that functions as an image bearer, a charger **402**, an exposing device **410**, a developing device **404**, a transfer device **405**, and a cleaning device **406**.

The charger **402** uniformly charges a surface of the photoconductor drum **401**.

The exposing device **410** is a latent image forming device to form an electrostatic latent image on the surface of the photoconductor drum **401** based on image data read by the image reading device **300**.

The developing device **404** supplies toner to adhere to the electrostatic latent image formed on the surface of the photoconductor drum **401** and develops the electrostatic latent image into a visible toner image.

The transfer device **405** is an image transfer body to transfer the visible toner image on the photoconductor drum **401** onto the sheet P.

The cleaning device **406** is a cleaner to remove residual toner remaining on the surface of the photoconductor drum **401** after transfer of the toner image onto the sheet P.

The image forming apparatus **2** further includes a fixing device **407** that is disposed downstream from the image forming part **420** in a sheet conveying direction. The fixing device **407** functions as a fuser to fix the toner image to the sheet P.

The exposing device **410** include a laser unit **411** and a polygon mirror **412**.

The laser unit **411** emits laser light based on the image data under control of a controller provided to the apparatus body **400**.

The polygon mirror **412** scans the laser light emitted by the laser unit **411** in a direction of rotation axis of the photoconductor drum **401** (i.e., in a main scanning direction).

The image reading device **300** functions as an image reader to read image data of an original document.

The ADF **500** is disposed above the image reading device **300** and is connected to the image reading device **300**. The ADF **500** includes a document table **501**, a document feed roller **502**, a transfer belt **503**, and a document discharging tray **504**.

When original documents are set on the document table **501**, upon receipt of a signal to start reading image data of the original documents, the document feed roller **502** of the ADF **500** feeds the original documents placed on the document table **501** one by one. Each original document fed by the document feed roller **502** is guided by the transfer belt **503** to a contact glass **309** and is halted on the contact glass **309** temporarily.

With the original document halted on the contact glass **309**, the image reading device **300** reads the image data of the original document. Thereafter, the transfer belt **503** resumes to convey the original document to the document discharging tray **504**.

Next, a description is given of a series of image reading processes and a series of image forming processes.

Either when the ADF **500** feeds the original document to the contact glass **309** or when a user places the original document on the contact glass **309** manually and inputs a copy start instruction via a control panel **200**, a light source **301** mounted on a first moving unit **303** emits light. Along with the light emission, the first moving unit **303** and a second moving unit **306** are moved along a guide rail.

As the light source **301** emits the light onto the original document placed on the contact glass **309**, the reflection light reflects on the original document. The reflection light is guided to a mirror **302** mounted on the first moving unit **303** and mirrors **304** and **305** mounted on the second moving unit **306** to a lens **307** so as to be received by a CCD **308**. As a result, the CCD **308** reads the image data of the original document and the read image data is converted from analog data to digital data by an analog/digital (A/D) conversion circuit provided to the image forming apparatus **2**. The image data is then transmitted from a data output port of the image reading device **300** to the controller of the apparatus body **400**.

By contrast, the apparatus body **400** starts driving the photoconductor drum **401**. As the photoconductor drum **401** rotates at a given speed, the charger **402** uniformly charges the surface of the photoconductor drum **401**. The exposing device **410** then exposes light to the surface of the photoconductor drum **401** to form the electrostatic latent image based on the image data read by the image reading device **300**.

Then, the developing device **404** develops the electrostatic latent image formed on the surface of the photoconductor drum **401** into a visible toner image. The sheet P is fed from a selected one of the sheet trays **430***a* and **430***b* by a corresponding one of the sheet feed rollers **414***a* and **414***b* and temporarily stopped at the registration roller pair **413**.

In synchronization with timing at which the leading end of the toner image formed on the surface of the photoconductor drum **401** reaches an image transfer part that is located facing the transfer device **405**, the registration roller pair **413** conveys the sheet P to the image transfer part. When the sheet P passes the image transfer part, the toner image formed on the surface of the photoconductor drum **401** is transferred onto the sheet P due to an action of an electric field in a transfer nip region.

Thereafter, the sheet P having the toner image on the surface thereof is conveyed to the fixing device **407** so that the fixing device **407** fixes the toner image to the sheet P. Then, the sheet P is discharged to the sheet finishing apparatus **3**.

It is to be noted that residual toner remaining on the surface of the photoconductor drum **401** without being transferred onto the sheet P at the image transfer part is removed from the photoconductor drum **401** by the cleaning device **406**.

A description is given of the sheet finishing apparatus **3** with reference to FIG. **18**.

FIG. **18** is a diagram illustrating a configuration of the sheet finishing apparatus **3** included in the image forming system **1** illustrated in FIG. **16**.

The sheet finishing apparatus **3** includes a first conveying path Pt**1**, a second conveying path Pt**2**, and a third conveying path Pt**3**. The first conveying path Pt**1** is a path through which the sheet P discharged from the image forming apparatus **2** travels to a first sheet discharging tray **10**. The second conveying path Pt**2** branches from the first conveying path Pt**1** to perform a side-stitching operation to a bundle of sheets. The third conveying path Pt**3** is connected to the second conveying path Pt**2** to perform a saddle-stitched center-folded sheet bundling operation to the bundle of sheets.

The first conveying path Pt**1**, the second conveying path Pt**2**, and the third conveying path Pt**3** are defined by guide members, for example.

The first conveying path Pt**1** includes an entrance roller **11**, a sheet conveying roller **12**, a sheet conveying roller **13**, and a sheet discharging roller **14**, which are disposed in this order along the first conveying path Pt**1** from an upstream side to a downstream side of the sheet conveying direction.

The entrance roller **11**, the sheet conveying roller **12**, the sheet conveying roller **13**, and the sheet discharging roller **14** are driven by a motor that functions as a driving source to convey a sheet of paper (i.e., the sheet P).

The first conveying path Pt**1** further includes an entrance sensor **15** disposed upstream from the entrance roller **11** in the sheet conveying direction. The entrance sensor **15** detects that the sheet P is conveyed into the sheet finishing apparatus **3**.

A switching claw **17** is disposed downstream from the sheet conveying roller **12** in the sheet conveying direction. The switching claw **17** switches the position by pivoting to selectively guide the sheet P to one of a downstream side of the switching claw **17** in the first conveying path Pt**1** in the sheet conveying direction and the second conveying path Pt**2**. The switching claw **17** is driven by a motor or a solenoid.

In a sheet discharging mode, the sheet P conveyed from the image forming apparatus **2** to the first conveying path Pt**1** is conveyed by the entrance roller **11**, the sheet conveying roller **12**, the sheet conveying roller **13**, and the sheet discharging roller **14** and is discharged to the first sheet discharging tray **10**.

By contrast, in a side stitching mode and a saddle stitching mode, the sheet P entered into the first conveying path Pt**1** is conveyed by the entrance roller **11** and the sheet conveying roller **12**, has a course of direction changed by the switching claw **17**, and is conveyed to the second conveying path Pt**2**.

The second conveying path Pt**2** includes a sheet conveying roller **20**, a sheet conveying roller **21**, a sheet conveying roller **22**, a sheet tray **23**, a first sheet aligning part **24**, and a side-stitching unit (a first stitching unit) **25**.

The sheet conveying roller **20**, the sheet conveying roller **21**, and the conveying roller **22** are driven by a motor. The first sheet aligning part **24** is driven by the motor.

Switching claws **26** and **27** are disposed at a downstream side of the sheet tray **23** in the sheet conveying direction. The switching claws **26** and **27** pivot to switch respective positions, so that the sheet P is selectively guided to one of the downstream side of the switching claw **17** in the first conveying path Pt in the first conveying path Pt**1** and the third conveying path Pt**3**. The switching claws **26** and **27** are driven by a motor or a solenoid, for example.

In the side stitching mode, multiple sheets P are sequentially loaded on the selected one of the sheet trays **23**. By so doing, the bundle of sheets including the multiple sheets P loaded thereon is formed. At this time, the trailing end of the bundle of sheets contacts a first movable reference fence that is disposed on the sheet tray **23** to align a position of the bundle of sheets in the sheet conveying direction and a width position of the bundle of sheets by the first sheet aligning part **24**.

The sheet tray **23**, the first sheet aligning part **24**, and the first movable reference fence form a first bundling part **28** that functions as a bundling part to make multiple sheets into a stacked sheet bundle. The first bundling part **28** further includes a motor to drive the first sheet aligning part **24** and a motor to drive the first movable reference fence.

The side-stitched sheet bundle is conveyed by the first movable reference fence to the first conveying path Pt**1**. Then, the sheet bundle is further conveyed by the sheet conveying roller **13** and the sheet discharging roller **14** to be discharged to the first sheet discharging tray **10**.

Here, the sheet discharging roller **14** functions as a sheet discharging member to discharge the sheet bundle that is bundled by the side stitching unit **25**. By contrast, in the center folding mode, the sheet P conveyed to the second conveying path Pt**2** is conveyed to the third conveying path Pt**3** by the sheet conveying rollers **20**, **21**, and **22**, and the first movable reference fence.

The third conveying path Pt**3** includes a sheet conveying roller **31**, a sheet conveying roller **32**, and a binding and folding part **33**.

A motor drives the sheet conveying rollers **31** and **32** to convey the sheet P. The binding and folding part **33** includes a center folding part **34**, a center stitching part (a second stitching unit) **35**, and a second bundling part **36**.

The sheet P conveyed to the third conveying path Pt**3** is conveyed by the sheet conveying rollers **31** and **32** one by one to the second bundling part **36**. As a result, a sheet bundle of layered multiple sheets P is made. Specifically, the second bundling part **36** makes a stacked sheet bundle with multiple sheets conveyed by a sheet conveying part **51** that includes the entrance roller **11** and the sheet conveying rollers **12**, **20**, **21**, **22**, **31**, and **32**.

At this time, the leading end of the sheet bundle including the sheets P contacts a second movable reference fence **37** to be aligned in the sheet conveying direction and contacts a second sheet aligning part to be aligned in a sheet width direction.

The center stitching part **35** stitches the sheet bundle at or in the vicinity of the center of the sheet bundle in the sheet conveying direction. The center-stitched sheet bundle is returned to a center folding position by the second movable reference fence **37**. The second movable reference fence **37** is driven by a motor.

The center folding part **34** folds the sheet bundle at the center thereof in the sheet conveying direction. In the center folding part **34**, a folding blade **38** is disposed to face the center of the sheet bundle at the center folding position in the sheet conveying direction. The folding blade **38** that is driven by a motor moves from right to left of FIG. **16** to fold the center of the sheet bundle in the sheet conveying direction to insert the sheet bundle between a lower pressure roller **39** and an upper pressure roller **40**.

The folded sheet bundle is pressed by the lower pressure roller **39** and the upper pressure roller **40**. The lower pressure roller **39** and the upper pressure roller **40** are driven by a motor.

The above-described center-folded sheet bundle is discharged by the lower pressure roller **39**, the upper pressure roller **40**, and a sheet discharging roller **41** to a second sheet discharging tray **42**.

A description is given of another example of the sheet discriminator **100** according to this example, with reference to FIGS. **19** through **21**.

FIG. **19** is a diagram illustrating another configuration of the sheet discriminator **100** included in the image forming system **1** of FIG. **16**.

Different from the previous example, this example includes the control panel **200** that functions as an indicator to indicate instructions to start sheet discrimination of the sheet P provided to the image forming apparatus **2**. Specifically, in the previous example, when an image is sequentially formed on multiple sheets of the same type, for example, sheet discrimination of the sheet P starts on insertion of the sheet P into the opening **102** of the sheet discriminator **100** even if the sheet P can be used without sheet discrimination. By contrast, in this example, sheet discrimination of the sheet P is performed when the control panel **200** provided to the image forming apparatus **2** issues instructions to the sheet discriminator **100** to do so. The other parts and functions are basically identical to the configuration of the sheet discriminator **100** of the previous example.

As illustrated in FIG. **19**, the sheet discriminator **100** according to this example is connected with the image forming apparatus **2** by a communication cable **60** that functions as a communicator. According to this configuration, the sheet discriminator **100** and the image forming apparatus **2** can communicate with each other.

The sheet P is inserted into the opening **102** of the sheet discriminator **100** that is connected to the image forming apparatus **2** via the communication cable **60** in the direction B until the sheet P contacts or approaches the end face **103** of the opening **102**. By so doing, the sheet information related to sheet types determined by the sheet discriminator **100** according to this example is transmitted to the image forming apparatus **2** via the communication cable **60**, so that appropriate image forming conditions can be set.

At this time, it is preferable that the operator grabs both left and right ends of the sheet P with respect to the direction B and inserts the sheet while checking that the sheet P has no deformation such as wrinkle or crease on the sheet P. It is to be noted that sheet insertion to the opening **102** is not limited to the above-described way but is applicable with any way of sheet insertion as long as the sheet P can be inserted into the opening **102** of the sheet discriminator **100** horizontally.

A description is given of a control of sheet discrimination with reference to FIGS. **20**A, **20**B, and **21**.

FIGS. **20**A and **20**B are cross sectional views of the sheet discriminator **100**, viewed from a direction indicated by arrow A in FIG. **19**. Specifically, FIG. **20**A is a cross sectional view illustrating the sheet discriminator **100** when the sheet P is inserted thereto through the opening **102** of the sheet discriminator **100** and FIG. **20**B is a cross sectional view illustrating the sheet discriminator **100** when the sheet P is pulled out from the opening **102** of the sheet discriminator **100**.

FIG. **21** is a flowchart illustrating an example of control of sheet discrimination performed by the sheet discriminator **100** illustrated in FIG. **19**.

The sheet discriminator **100** receives instructions to start the sheet discrimination of the sheet P via the control panel **200** that is mounted on the image forming apparatus **2**, as described in step S**11** in the flowchart of FIG. **21**. After the operation of step S**11** in FIG. **21** is completed, the light emission processing unit **130** of the sheet discriminator **100** caused the sheet information detecting sensor **110** to start emitting light, as described in step S**12** in the flowchart of FIG. **21**. Then, as illustrated in FIG. **20**A, the sheet P is inserted toward the end face **103** of the opening **102** of the sheet discriminator **100** in the direction C, as described in step S**13** in the flowchart of FIG. **21**.

The sheet information detecting sensor **110** performs at least one information detection, i.e., the first information detection(s) D**1** in FIG. **20**A with respect to the sheet P that is inserted toward the end face **103** of the opening **102**. Further, the sheet thickness detecting sensor **170** detects the thickness of the sheet P when the sheet P is inserted toward the end face of the opening **102**, as described in step S**14** in the flowchart of FIG. **21**.

By employing the sheet thickness detecting sensor **170** to detect the thickness of the sheet P as described above, even when a thick paper is used as the sheet P, the thickness of the sheet P can be detected more accurately compared to the case in which the thickness of the sheet P is obtained based on detection results of the transmitted light received by the receiver **160**.

After the sheet P has reached the end face **103** of the opening **102**, the sheet P is removed. When pulling out the sheet P from the opening **102**, the sheet P moves in a direction indicated by arrow D in FIG. **20**B. At this time, the sheet information detecting sensor **110** performs at least another one information detection, i.e., the second information detection(s) D**2** in FIG. **20**B. Accordingly, the sheet information detecting sensor **110** detects the sheet P at different points on the sheet P in the first information detection D**1** and the second information detection D**2**.

As described above, the sheet discriminator **100** according to this example slides the sheet P in the opening **102** for multiple detections. Based on the information obtained by the sheet information detecting sensor **110**, the controller **600** discriminates the sheet P, as described in step S**15** in FIG. **21**.

At this time, by including the detection results obtained by the sheet thickness detecting sensor **170** to the sheet information used to distinguish the sheet P by the controller **600**, the sheet P can be discriminated using the information regarding the sheet P having the thickness precisely detected. As a result, the sheet discriminator **100** according to this example can prevent degradation of accuracy of sheet discrimination due to inaccurate detection of the thickness of the sheet P when a thick paper is used as the sheet P.

After the sheet P is removed from the opening **102** and the thickness thereof is not detected by the sheet thickness detecting sensor **170**, which is YES in step S**16** in FIG. **21**, the light emission processing unit **130** causes the sheet information detecting sensor **110** to stop light emission, as described in step S**17** in FIG. **21**. When the thickness of the sheet P is detected by the sheet thickness detecting sensor **170**, which is NO in step S**16** in FIG. **21**, the procedure is repeated until the thickness of the sheet P is not detected by the sheet thickness detecting sensor **170**.

Further, based on detection results regarding the sheet P obtained by the sheet discriminator **100**, possible sheet brands, sizes, manufacturers, etc. of the sheet P that is inserted into the sheet discriminator **100** through the opening **102** are displayed on a display of the control panel **200**, as described in step S**18** of FIG. **21**. Then, the controller **600** completes the control of sheet discrimination using the sheet discriminator **100** illustrated in FIGS. **20**A and **20**B, and sets the image forming conditions according to a correct type of the sheet P out of the listed sheet brands, sizes, and so forth displayed on the control panel **200** to perform image formation.

Further, the sheet discriminator **100** according to this example causes the sheet information detecting sensor **110** to emit light when the control panel **200** indicates to start the sheet discrimination and the sheet information detecting sensor **110** detects information of the sheet P. Accordingly, when compared with a case in which the sheet information detecting sensor **110** constantly emits light, the sheet discriminator **100** according to this example can extend the life span of the sheet information detecting sensor **110** and reduce waste energy consumption thereof.

As described above, in this example, the light source **111** of the sheet information detecting sensor **110** starts light emission when the control panel **200** indicates to start sheet discrimination. However, alternatively, the light source **111** can start light emission when the sheet thickness detecting sensor **170** detects the thickness of the sheet P.

By so doing, compared to a series of operations in which the light source **111** starts light emission, the sheet P is inserted into the opening **102**, and the sheet information detecting sensor **110** detects information of the sheet P, a time from the start of light emission to the completion of detection can be shortened. Accordingly, the time of light emission of the sheet information detecting sensor **110** can be shortened, and therefore the sheet discriminator **100** according to this example can extend the life span of the sheet information detecting sensor **110** and reduce waste energy consumption thereof.

Thus, in the sheet discriminator **100** according to this example similar to the sheet discriminator **100** according to the previous example, the controller **600** regulates timing to cause the light source **111** of the sheet information detecting sensor **110** to start or stop light emission based on the detection results obtained by the sheet thickness detecting sensor **170**.

Accordingly, the sheet discriminator **100** according to this example can contribute to a reduction in cost when compared with the case in which a sheet detecting sensor to detect whether the sheet P is present or absent at a given position on the sheet loading table **120** is provided to the sheet discriminator **100** to regulate the timing to cause the light source **111** to start or stop light emission based on detection results obtained by the sheet detecting sensor.

It is to be noted that the image forming apparatus **2** included in the image forming system **1** according to this example can be any one of a digital copier, a printer, an offset printer, and other image forming apparatuses.

It is also to be noted that the sheet discriminator **100** mounted on the image forming apparatus **2** can be any one of the sheet discriminators **100** according to the above-described examples of this disclosure.

Next, a description is given of a sheet discriminator **100** according to another example of this disclosure, with reference to FIGS. **22** through **26**.

FIG. **22** is an exploded view illustrating a sheet discriminator **100** according to an example of this disclosure.

The sheet discriminator **100** includes a sheet information detector module **880**, a sheet thickness detecting unit **870**, the sheet loading table **120**, and a base unit **890**.

The sheet information detector module **880** functions as a detector body to include the sheet information detecting sensor **110**, a case **820**, and a cover **830**.

The sheet information detecting sensor **110** includes the light source **111**. The case **820** holds the sheet information detecting sensor **110** and includes a measuring reference face **901** (see FIG. **23**) when measuring the thickness of the sheet P. The cover **830** covers the case **820**. The measuring reference face **901** that functions as an opposing member is disposed facing an encoder feeler **704** provided to the sheet thickness detecting sensor **170**.

The configuration of the sheet information detecting sensor **110** and detection principle of sheet information performed the sheet information detecting sensor **110** are the same as those described with reference to FIGS. **3** through **10**.

The sheet thickness detecting unit **870** includes the sheet thickness detecting sensor **170** and a sensor attaching bracket **701**.

The sensor attaching bracket **701** holds the sheet thickness detecting sensor **170**.

The sheet thickness detecting sensor **170** is an encoder that functions as a displacement unit to detect an amount of displacement according to thickness of the sheet P.

The configuration of the sheet thickness detecting sensor **170** and detection principle of sheet thickness performed the sheet thickness detecting sensor **170** are the same as those described with reference to FIGS. **11**, **12**, **13**A, and **13**B.

The sensor attaching bracket **701** is formed by engineering plastics having excellent rigidity such as ABS (Acrylonitrile-Butadiene-Styrene) resin or by metallic material.

The control of sheet discrimination is the same as those described with reference to FIGS. **2**A, **2**B, and **11**.

The base unit **890** includes a base **860** and a cover **850**.

The sheet thickness detecting unit **870** and the sheet loading table **120** to load the sheet P thereon are provided inside the base **860**.

The sheet information detector module **880** is supported by the base unit **890**.

FIG. **23** is a cross sectional view illustrating the sheet discriminator **100** illustrated in FIG. **22**. It is to be noted that the base unit **890** is omitted, for convenience.

A side of the sensor attaching bracket **701**, which is opposite to another side on which the sheet thickness detecting sensor **170** is mounted, is fixed by a screw or screws to a lower part of the case **820**.

In FIG. **23**, the sheet P is inserted from a direction indicated by arrow E (hereinafter, a direction E) into a gap formed between the measuring reference face **901** that is a lower face of the case **820** and the sheet loading table **120**. The sheet loading table **120** includes the biasing member **150** such as a spring that is attached to a position facing the sheet information detecting sensor **110**. Accordingly, the sheet loading table **120** is biased by the biasing member **150** toward the measuring reference face **901**. The surface of the sheet P inserted between the measuring reference face **901** and the sheet loading table **120** is pressed against the measuring reference face **901** by the sheet loading table **120**.

When the sheet information detecting sensor **110** detects sheet information, the light source **111** emit light toward the surface of the sheet P. Since the surface of the sheet P is pressed onto the measuring reference face **901**, the sheet information detecting sensor **110** takes the measuring reference face **901** as a reference face for the measurement of the sheet P.

In the sheet discriminator **100** illustrated in FIG. **23**, the sheet thickness detecting sensor **170** is disposed downstream from the sheet information detecting sensor **110** in the sheet inserting direction, which is the direction E. However, the sheet thickness detecting sensor **170** can be disposed upstream from the sheet information detecting sensor **110** in the direction E.

FIG. **24**A is a diagram illustrating a state in which the encoder feeler **704** provided to the sheet thickness detecting sensor **170** of the sheet discriminator **100** according to this example before the sheet P is inserted. FIG. **24**B is a diagram illustrating a state in which the encoder feeler **704** after the sheet P is inserted. The encoder feeler **704** functions as a displacement gauge.

In the state before the sheet P is inserted as illustrated in FIG. **24**A, the encoder feeler **704** of the sheet thickness detecting sensor **170** is in contact with the measuring reference face **901**. When the sheet P is inserted as illustrated in FIG. **25**B, the encoder feeler **704** of the sheet thickness detecting sensor **170** contacts the surface of the sheet P to measure the thickness of the sheet P. Since the surface of the sheet P is pressed to the measuring reference face **901**, when the sheet thickness detecting sensor **170** detects the thickness of the sheet P, the sheet thickness detecting sensor **170** also takes the measuring reference face **901** as a reference face for the measurement.

The sheet information detector module **880** warps or bends under its own gravity as well as due to a load that is intentionally applied by the hand of an operator placed on an upper part of the sheet information detector module **880**.

FIGS. **25**A and **25**B are diagrams illustrating respective positional relations of the measuring reference face **901** and the sheet thickness detecting sensor **170** when the sheet information detector module **880** of the sheet discriminator **100** is warped or bent by receiving any load.

Specifically, FIG. **25**A is a diagram illustrating a comparative example of a positional relation of the measuring reference face **901** and the sheet thickness detecting sensor **170** attached directly to the base **860**.

When a load is applied to a point on the sheet information detector module **880** in a direction indicated by arrow F (hereinafter, a direction F) in FIG. **25**A, the point of the sheet information detector module **880** inclines downwardly due to the load, and therefore the measuring reference face **901** also inclines downwardly along with the sheet information detector module **880**. As the measuring reference face **901** inclines downwardly, the position at which the measuring reference face **901** is formed approaches the sheet thickness detecting sensor **170**. Therefore, the thickness of the sheet P is measured thinner by an amount of approach of the measuring reference face **901** to the sheet thickness detecting sensor **170**.

The thickness of the sheet P ranges from several tens micrometers [μm] to several hundreds micrometers [μm] and the minimum scanning resolution of the sheet thickness detecting sensor **170** is 5 μm. Accordingly, even small warp or deformation of the sheet information detector module **880** is formed, the effects on measurement of the thickness of the sheet P cannot be ignored.

By contrast, FIG. **25**B is a diagram illustrating this example of a positional relation of the measuring reference face **901** and the sheet thickness detecting sensor **170** attached to the base **860** via the sensor attaching bracket **701**. As illustrated in FIG. **25**B, by attaching the sheet thickness detecting sensor **170** to the sheet information detector module **880** via the sensor attaching bracket **701**, even when the measuring reference face **901** inclines downwardly, the sheet thickness detecting sensor **170** inclines downwardly together with the measuring reference face **901**. Accordingly, disturbance to the sheet information detector module **880** is restrained to the minimum amount, and therefore sufficient measurement accuracy can be achieved.

FIG. **26** is a graph showing results of tests regarding effectiveness to prevent misdetection in measurement of the thickness of the sheet P when the sheet information detector module **880** of the sheet discriminator **100** is warped intentionally.

The tests were conducted to measure display values of the sheet thickness detecting sensor **170** (i.e., amounts of displacement obtained by the encoder feeler **704**) when a load applied in the direction F in FIGS. **25**A and **25**B at one end of the sheet information detector module **880**. It is ideal that the display values obtained by the sheet thickness detecting sensor **170** do not rise even when the load applied to the sheet information detector module **880** is increased.

When the sheet thickness detecting sensor **170** is mounted directly on the base **860**, which is "before taking the countermeasure", as the load applied to the sheet information detector module **880** increases, the display values of the sheet thickness detecting sensor **170** also increases significantly. Since the thickness of the sheet P ranges from several tens micrometers [μm] to several hundreds micrometers [μm], the thickness of the sheet P cannot be measured precisely when disturbance was caused "before taking the countermeasure".

By contrast, when the sheet thickness detecting sensor **170** is mounted on the sheet information detector module **880** via the sensor attaching bracket **701**, which is "after taking the countermeasure", a rate of an increase in the display values of the sheet thickness detecting sensor **170** to which disturbance is caused can be reduced and restrained to $\frac{1}{10}$ to $\frac{1}{6}$, compared to an increase in the display values obtained "before taking the countermeasure".

Next, a description is given of the image forming system **1** according to another example of this disclosure.

The schematic configuration of the image forming system **1** according to this example is basically identical to the configuration of the image forming system **1** illustrated in FIG. **16**, except for the function of the sheet discriminator **100** provided to the image forming system **1** according to this example.

Specifically, the schematic configuration of the sheet discriminator **100** according to this example is basically identical to the configuration of the sheet discriminator **100** described above with reference to FIGS. **22** and **23**. Except, the sheet discriminator **100** according to this example uses the control panel **200** provided to the image forming apparatus **2**.

The control panel **200** is provided to the image forming apparatus **2** to function as an indicator to indicate instructions to the sheet discriminator **100** to start sheet discrimination of the sheet P. Specifically, in the previous example, when an image is sequentially formed on multiple sheets of the same type, for example, sheet discrimination of the sheet P starts on insertion of the sheet P into the opening **102** of the sheet discriminator **100** even if the sheet P can be used without sheet discrimination.

By contrast, in this example, sheet discrimination of the sheet P is performed when the control panel **200** provided to the image forming apparatus **2** issues instructions to the sheet discriminator **100** to do so. The other parts and functions are basically identical to the configuration of the sheet discriminator **100** illustrated in FIGS. **20**A, **20**B, and **21**.

The configurations according to the above-described embodiment are examples. The present invention can achieve the following aspects effectively.

Aspect A.

In Aspect A, a sheet discriminator (for example, the sheet discriminator **100**) includes an optical information detector (for example, the sheet information detecting sensor **110**), the sheet distinguisher (for example, the controller **600**), and a sheet thickness detector (for example, the sheet thickness detecting sensor **170**). The optical information detector includes a light emitter (for example, the light source **111**) to emit light to a surface of a recording medium (for example, the sheet P) and a light receiver (for example, the receivers **113**, **114**, **115**, **118**, and **160**) to receive the light emitted by the light emitter and to detect information of the recording medium. The sheet distinguisher distinguishes a type of the recording medium based on the information detected by the optical information detector. The sheet thickness detector includes a displacement gauge (for example, the feeler **171** and the encoder feeler **704**) and a displacement detector (for example, the optical sensor **172**). The displacement gauge sandwiches the recording medium with an opposing member (for example, the bottom face **110***a* of the sheet information detecting sensor **110**, the measuring reference face **901**) disposed facing the displacement gauge and moves from an initial position at which the displacement gauge stays when no recording medium is sandwiched with the opposing member. The displacement detector detects an amount of displacement of the displacement gauge. The sheet thickness detector detects a thickness of the recording medium based on detection results obtained by the displacement detector.

In Aspect A, by sandwiching the recording medium between the displacement gauge and the opposing member, the sheet thickness detector can detect the thickness of the recording medium based on an amount of displacement of the displacement gauge physically moved from the initial position according to the thickness of the recording medium. Accordingly, even though the recording medium has a thickness difficult for the optical sheet information detector to precisely detect optically, the sheet thickness detector can detect the thickness of the sheet P accurately. By so doing, the recording medium can be discriminated using information related to the thickness of the recording medium that is detected accurately. As a result, the sheet discriminator can prevent degradation of accuracy of sheet discrimination of the recording medium.

Aspect B.

In Aspect A, the sheet discriminator further includes a light emission controller (for example, the light emission processing unit **130**) to control start and stop of the light emitter. When the sheet thickness detector detects the thickness of the recording medium, the light emission controller causes the light emitter to start light emission.

Accordingly, as described in the examples above, the recording medium is inserted into the sheet discriminator, the sheet information detector can start light emission without any operator handling. Consequently, when compared with a case in which the light emission controller does not control light emission of the sheet information detector and the sheet information detector constantly emits light, the life span of the sheet information detector including the light emitter can be extended.

Aspect C.

In Aspect B, when the sheet thickness detector detects no thickness of the recording medium, the light emission controller causes the light emitter to stop light emission.

Accordingly, as described in the examples above, when the recording medium is pulled out from the sheet discriminator, the light emitter of the sheet information detector can stop light emission without any operator handling.

Aspect D.

In Aspect B, when the optical information detector completes detection of information of the recording medium, the light emission controller causes the light emitter to stop light emission.

Accordingly, as described in the examples above, when the recording medium is pulled out from the sheet discriminator, the light emitter of the sheet information detector can stop light emission without any operator handling.

Aspect E.

In any one of Aspects A through D, the light emitter emits laser light.

Accordingly, as described in the examples above, the surface information of the recording medium can be detected more precisely, and therefore more precise detection results can be obtained.

Aspect F.

In any one of Aspects A, B, C, D, and E, the light receiver of the optical information detector includes multiple light receivers. The multiple light receivers includes at least a transmitted light receiver (for example, the receiver **160**) to receive transmitted light that is transmitted through the recording medium out of the light emitted from the light emitter.

Accordingly, as described in the examples above, when the thickness of the recording medium is thin, the level of light received by the transmitted light receiver is additionally used as sheet information to obtain the thickness of the recording medium. By so doing, the accuracy of sheet discrimination can be more enhanced.

Aspect G.

In any one of Aspects A through F, the light receiver of the optical information detector includes multiple light receivers. The multiple light receivers include at least a specular reflection light receiver (for example, the receiver **113**) to receive specular reflection light emitted from the light emitter and reflected on the recording medium and a diffused reflection light receiver (for example, the receiver **115**) to receive diffused reflection light emitted from the light emitter and reflected on the recording medium.

Accordingly, as described in the examples above, the multiple light receivers disposed at different angles can detect scattered light beams of diffused reflection light, and therefore more precise detection results of information can be obtained than the information obtained from specular reflection light alone.

Aspect H.

In any one of Aspects A through G, the sheet discriminator further includes a communicator (for example, the communication cable **60**) disposed between the sheet discriminator and an image forming apparatus (for example, the image forming apparatus **2**) to communicate with each other.

Accordingly, as described in the examples above, after the sheet discriminator discriminates the information related to the type of the recording medium, the information is sent to the image forming apparatus via the communicator. By so doing, the image forming conditions according to a correct type of the recording medium can be set.

Aspect I.

In any one of Aspects A through H, the sheet discriminator further includes a detector body (for example, the sheet information detector module **880**) to include the opposing member and the displacement detector and to maintain a position of the opposing member relative to the displacement detector.

In the sheet discriminator **100**, the sheet information detector module **880** that functions as the detector body includes the measuring reference face **901** that functions as the opposing member. When the sheet information detector module **880** receives an external force, a position of the measuring reference face **901** relative to the base unit **890** changes. In a case in which the sheet thickness detecting sensor **170** including the optical sensor **172** that functions as the displacement detector is mounted on the base unit **890**, a position of the measuring reference face **901** relative to the sheet thickness detecting sensor **170** also changes. When the sheet thickness detecting sensor **170** measures the thickness of the sheet P, the amount of positional shift or movement of the measuring reference face **901** relative to the sheet thickness detecting sensor **170** is counted as measurement error. By attaching the sheet thickness detecting sensor **170** to the sheet information detector module **880** that includes the measuring reference face **901**, regardless of the external force applied to the detector body, sufficient measurement accuracy can be achieved when the sheet thickness detecting sensor **170** detects or measures the thickness of the recording medium.

Aspect J.

In Aspect J, an image forming apparatus (for example, the image forming apparatus **2**) includes an apparatus body (for example, the apparatus body **400**), an image forming part (for example, the image forming part **420**) to form an image on the recording medium, and the sheet discriminator (for example, the sheet discriminator **100**) to detect information of the recording medium and discriminate a type of the recording medium. The sheet discriminator of the image forming apparatus is the sheet discriminator according to any one of Aspects A through I and is disposed outside the apparatus body.

Accordingly, as described above, the sheet discriminator can detect the thickness of the recording medium precisely, and therefore can prevent degradation of accuracy of sheet discrimination and can perform image formation under appropriate image forming conditions according to a correct type of the recording medium.

Aspect K.

In Aspect J, the image forming apparatus further includes an indicator (for example, the control panel **200**) disposed on the apparatus body and indicating instructions to the light emission controller.

Accordingly, as described in the examples above, an operator inputs instructions via the indicator to cause the sheet information detector to detect information of the recording medium, so that the light emitter can start light emission.

The above-described embodiments are illustrative and do not limit this disclosure. Thus, numerous additional modifications and variations are possible in light of the above teachings. For example, elements at least one of features of different illustrative and exemplary embodiments herein may be combined with each other at least one of substituted for each other within the scope of this disclosure and appended claims. Further, features of components of the embodiments, such as the number, the position, and the shape are not limited the embodiments and thus may be preferably set. It is therefore to be understood that within the scope of the appended claims, the disclosure of this disclosure may be practiced otherwise than as specifically described herein.

What is claimed is:

1. A sheet discriminator, comprising:

an optical information detector including a light emitter and a light receiver, the light emitter configured to emit light to a surface of a sheet, the light receiver configured to receive the light emitted by the light emitter and reflected by the surface of the sheet, the optical information detector configured to detect information of the sheet based on the received light;

a sheet distinguisher configured to distinguish a type of the sheet based on the information detected by the optical information detector; and

a sheet thickness detector including a displacement gauge and a displacement detector, the displacement gauge configured to sandwich the sheet with an opposing member facing the displacement gauge and to move from an initial position at which the displacement gauge stays when no sheet is sandwiched with the opposing member, the displacement detector configured to detect an amount of displacement of the displacement gauge and detect a thickness of the sheet based on detection results obtained by the displacement detector.

2. The sheet discriminator according to claim **1**, further comprising:

a light emission controller configured to control start and stop of the light emitter,

wherein, when the sheet thickness detector detects the thickness of the sheet, the light emission controller is configured to cause the light emitter to start light emission.

3. The sheet discriminator according to claim **2**, wherein, when the sheet thickness detector detects no thickness of the sheet, the light emission controller is configured to cause the light emitter to stop light emission.

4. The sheet discriminator according to claim **3**, wherein the light emitter is configured to emit laser light.

5. The sheet discriminator according to claim **3**, wherein the light receiver of the optical information detector includes multiple light receivers, the multiple light receivers including at least a transmitted light receiver configured to receive transmitted light transmitted through the sheet out of the light emitted from the light emitter.

6. The sheet discriminator according to claim **3**, wherein the light receiver of the optical information detector includes multiple light receivers, the multiple light receivers including at least a specular reflection light receiver and a diffused reflection light receiver, the specular reflection light receiver configured to receive specular reflection light emitted from the light emitter and reflected on the sheet, the diffused reflection light receiver configured to receive diffused reflection light emitted from the light emitter and reflected on the sheet.

7. The sheet discriminator according to claim **3**, further comprising:

a communicator between the sheet discriminator and an image forming apparatus, the communicator configured to communicate with each other.

8. The sheet discriminator according to claim **2**, wherein, when the optical information detector completes detection of information of the sheet, the light emission controller is configured to cause the light emitter to stop light emission.

9. The sheet discriminator according to claim **2**, wherein the light emitter is configured to emit laser light.

10. The sheet discriminator according to claim **2**, wherein the light receiver of the optical information detector includes multiple light receivers, the multiple light receivers including at least a transmitted light receiver configured to receive transmitted light transmitted through the sheet out of the light emitted from the light emitter.

11. The sheet discriminator according to claim **2**, wherein the light receiver of the optical information detector includes multiple light receivers, the multiple light receivers including at least a specular reflection light receiver and a diffused reflection light receiver, the specular reflection light receiver configured to receive specular reflection light emitted from the light emitter and reflected on the sheet, the diffused reflection light receiver configured to receive diffused reflection light emitted from the light emitter and reflected on the sheet.

12. The sheet discriminator according to claim **2**, further comprising:

a communicator between the sheet discriminator and an image forming apparatus, the communicator configured to communicate with each other.

13. The sheet discriminator according to claim **2**, further comprising:

a detector body including the opposing member and the displacement detector, the detector body configured to maintain a position of the opposing member relative to the displacement detector.

14. The sheet discriminator according to claim **1**, wherein the light emitter is configured to emit laser light.

15. The sheet discriminator according to claim **1**, wherein the light receiver of the optical information detector includes multiple light receivers, the multiple light receivers including at least a transmitted light receiver configured to receive transmitted light transmitted through the sheet out of the light emitted from the light emitter.

16. The sheet discriminator according to claim **1**, wherein the light receiver of the optical information detector includes multiple light receivers, the multiple light receivers including at least a specular reflection light receiver and a diffused reflection light receiver, the specular reflection light receiver configured to receive specular reflection light emitted from the light emitter and reflected on the sheet, the diffused reflection light receiver configured to receive diffused reflection light emitted from the light emitter and reflected on the sheet.

17. The sheet discriminator according to claim **1**, further comprising:

a communicator between the sheet discriminator and an image forming apparatus, the communicator configured to communicate with each other.

18. The sheet discriminator according to claim **1**, further comprising:

a detector body to include the opposing member and the displacement detector, the detector body configured to maintain a position of the opposing member relative to the displacement detector.

19. An image forming apparatus comprising:

an apparatus body;

a sheet discriminator disposed outside the apparatus body, the sheet discriminator including,

an optical information detector including a light emitter and a light receiver, the light emitter configured to emit light to a surface of a sheet, the light receiver configured to receive the light emitted by the light emitter and reflected by the surface of the sheet, the optical information detector configured to detect information of the sheet based on the received light,

a sheet distinguisher configured to distinguish a type of the sheet based on the information detected by the optical information detector, and

a sheet thickness detector including a displacement gauge and a displacement detector, the displacement gauge configured to sandwich the sheet with an opposing member facing the displacement gauge and to move from an initial position at which the displacement gauge stays when no sheet is sandwiched with the opposing member, the displacement detector configured to detect an amount of displacement of the displacement gauge and detect a thickness of the sheet based on detection results obtained by the displacement detector; and

an image forming part to form an image on the sheet.

20. The image forming apparatus according to claim **19**, further comprising:

an indicator on the apparatus body, the indicator configured to indicate instructions to the light emission controller.

* * * * *